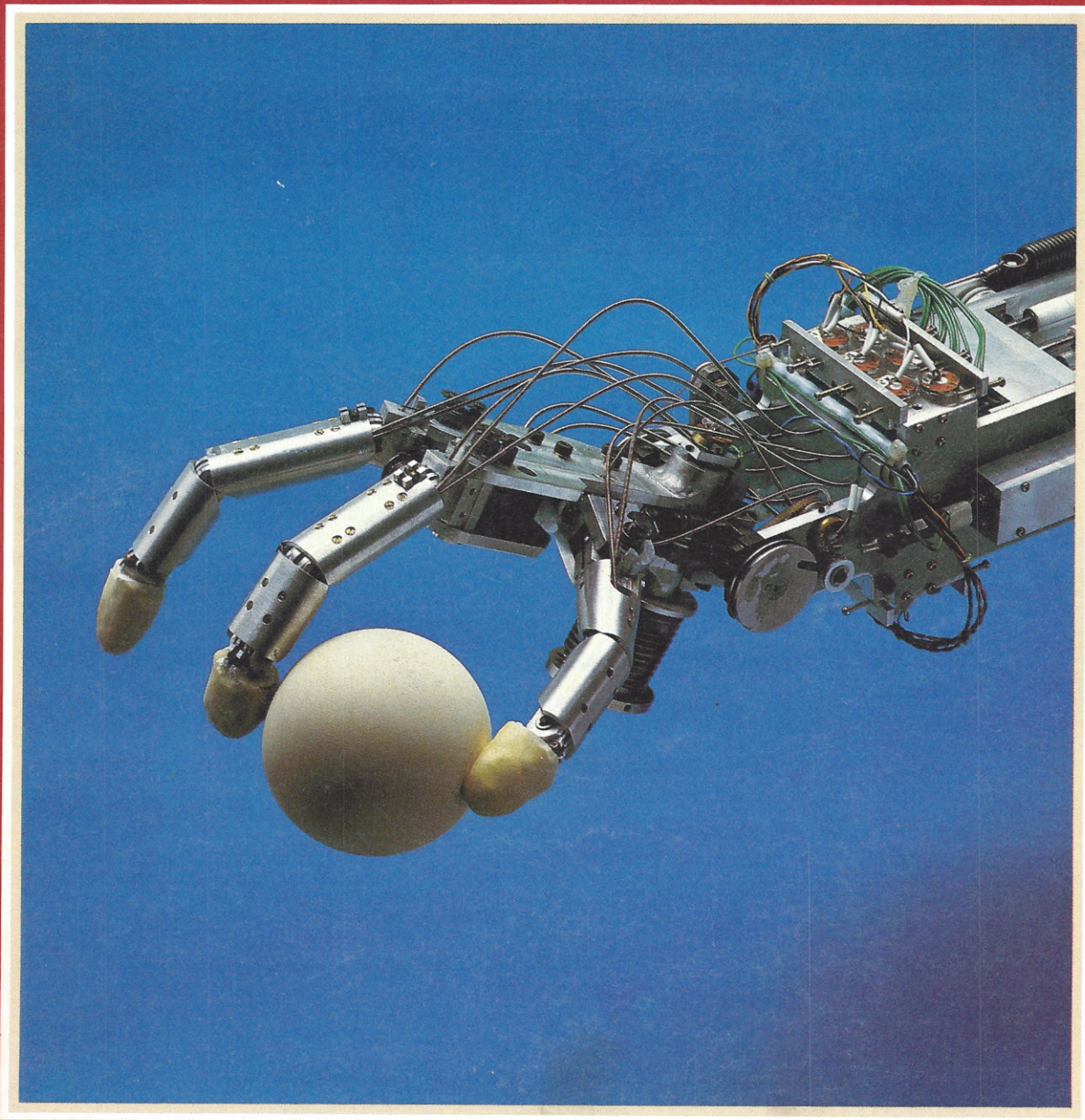


JULY 1984 VOL. 6 NO. 7

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THE JOURNAL OF INTELLIGENT MACHINES

ROBOTICSTM AGE

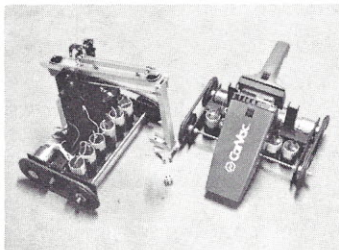


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KITTEN MINI ROVER A smaller, 6" system, includes same 7 channel RC, motor controller and computer interface. KIT \$200. ASSY \$330.

MINI ARM (the cats paw) adds pick up action. KIT \$60. ASSY \$100.

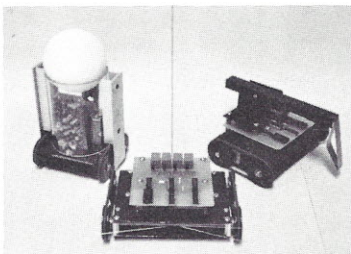
RUG RAT (R2 micro rover) slightly smaller. KIT \$200. ASSY \$330.

NAVIGATION AND TRACKING INQUIRE

ROVER ROBOT SYSTEM A medium weight (9 lb, 12" wide) computer controlled robot with radio link. With RC etc. KIT \$350. ASSY \$580.

VACUUM CLEANER ADD ON UNIT. A 12V Black and Decker vacuum cleaner with control circuit and height control RC. KIT \$90. ASSY \$150.

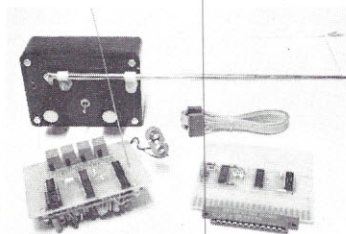
ARM ADD ON UNIT (see ROBOT IV) Allows mobile robot to pick up objects. KIT \$150. ASSY \$250.



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RADIO CONTROL SYSTEMS Allows your full computer power to be used to control one or more mobile robots. Also allows tracking with stationary vision units and memory intensive room mapping for practical chores. Bidirectional DUPLEX RC available, inquire. See catalog for servos etc. RC systems include user port interface for VIC/C64 and also allow manual radio control of robots.



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AUDIO COMMUNICATION LINK Analog/digital return path from sensors on robot. KIT \$25. ASSY \$40.

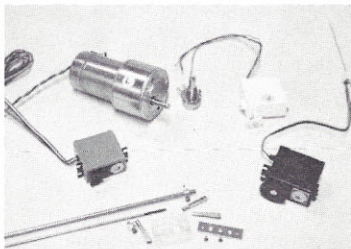
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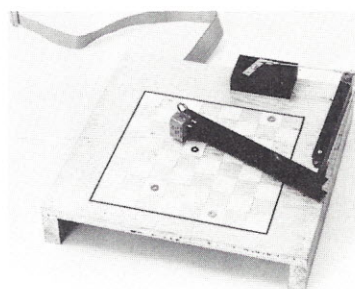
EDUCATORS

We offer hardware and courseware for demonstrations, lab work and student projects in all areas of ROBOTICS, MACHINE VISION and ARTIFICIAL INTELLIGENCE. Our modular systems allow both students and instructors to start with low cost and easy to understand systems and progress in logical steps to state of the art technology. TRULY EDUCATION ORIENTED FOR TOMORROW!

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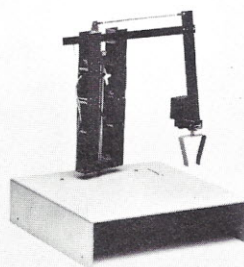
ROBOT I Two axis robot arm. Can draw, pick up game markers, etc. A good introduction to coordinate transformations, teach mode and direct programming, and robotic hardware. KIT \$125. ASSY \$210

ROBOT I + VIS COMBINATION PACKAGE With vision system which allows part recognition, sorting and alignment, and VIC ADX interface circuit. KIT \$200. ASSY \$330.



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VISION—OUR STRONGEST AREA

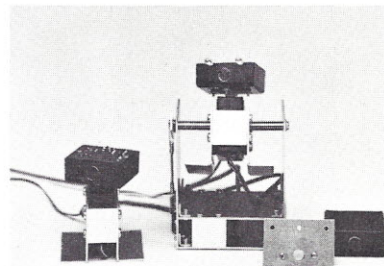
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THE JOURNAL OF INTELLIGENT MACHINES

ROBOTICS AGE™

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About the cover: New applications of shape memory effect alloys have produced small, lightweight, and powerful robot manipulators. This month's cover shows an experimental hand developed by Hitachi.

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ENTER THE SERVICE ROBOT

"That's a very nice-looking robot. What does it do?"

That question seems to evoke groans and sighs from just about everyone who knows that the current "personal" robots aren't supposed to "do" anything. I agree that the major use for the current crop of robots is experimentation and education. The Heath HERO 1 is a prime example of a robot aimed squarely at this educational market and which has captured a sizeable portion of that market. However, there are a limited number of schools out there wishing to purchase a \$1500 dollar machine.

There seem to be few, if any, robot manufacturers in either the industrial or experimental marketplace that are showing a profit. Every time I turn around, I hear about another robot manufacturer in financial trouble. A recent report on industrial robots suggests that none of the major manufacturers are showing profits. At the same time, major personal robot manufacturers like Androbot and RB Robot are also having financial difficulties. So, how do you make

any money with robots? One possibility is to consider another class of robot, the *service* robot.

Service robots are not exactly industrial, nor are they personal machines. Service robots are small, well-constructed, motile beasts that *do something*. That's the key idea. It probably doesn't matter what they do, as long as it is something useful, necessary, and economically sound. Now, in general terms, what segment of the American market is large, always looking for new ways to improve business, and wants economical solutions? Answer—the small business owner. A large part of the American economy is built around small shops and businesses. Let's design a robot which is useful for the business consumer.

EVERYONE'S DREAM APPLICATION

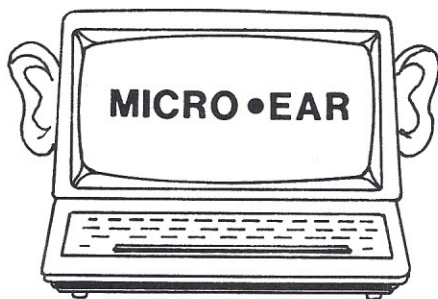
For years people have talked about building a robot that vacuums the house. Although several robots are supposed

Continued on page 42.

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- Complete instructions, schematics, training sessions, operational hints, and demo software are included

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Letters

What to do with a Robot

"Well R2, I think we should go this way, I am sure that this is the way we want to go." I believe I have heard this phrase uttered from the mechanical voice box of an all-too-well-known robot, C3PO. The rest of the story is that this rather articulate robot walks off into the sunset with his little buddy R2D2 following close behind.

This scene, the hero and his sidekick, has been stolen from every cowboy movie ever made. Unbelievably, there are people waiting for these creatures to show up in their own daily lives. The purpose? To clean house, fix machinery, and have outrageous space adventures.

I have no doubt that after a few technical quantum leaps, such creatures will be bothering humanity. Until then, I think we need to look at just what the technology of today can do to entertain and help us in our daily work. The following opinions are my own and are not necessarily based on hard fact. However, I believe my thoughts are valid.

"Don't be a pioneer" is an operating assumption of the company for which I work, Link Telecommunications, Inc. Pioneers get arrows in their backs. Use what has already been proven to do the job. This applies in the utmost to robots. Link Telecommunications is not trying to make these little creatures climb stairs, clean the pool, or cook dinner (at least not at first). However, we have found some very simple and useful tasks that robots can do today.

Some of the things listed here are already being developed and will probably be found on retail shelves this fall and next spring. Some are projects that won't materialize for a year or two.

Robot portable telephone—I hate getting up to answer the phone. It makes more sense to have the phone come to you.

Home security robot—fire alarms, intrusion alarms, and motion alarms are currently devices that hang on the wall and usually look out of place. Why not have a cute robot to do these tasks?

Interoffice mail delivery—I know that there are some of these devices out now, but they cost too much. A really inexpensive mail deliverer would allow each person, or group of people, to have their own private message robot. They could send the robot off to its destination and expect it to come back after delivering the message.

Playmates for children—when combined with control languages like Logo or Androtext robots are more fun than the old dirt-in-the-truck routine. For that matter, personal robots should be constructed to work in backyard dirt and lawns.

Health care units—robots could take blood pressure and other vital signs and keep the doctor informed of the results. Robots could be companions for elderly folks who have trouble getting around. Robots would also be useful for bringing household items to anyone whose motion is restricted.

Toys—what's wrong with a toy robot that does more than just walk into walls? It doesn't have to do much. I personally like toys and would appreciate a well-made toy robot to while away some of the boredom of a rainy weekend.

Measuring tools—put a laser rangefinding system in the robot's head and construction crews would have a handy device for measuring distances.

Prison guards—use a robot to walk up and down the halls making bed checks. If the robot get damaged, it can be replaced. A human life is priceless.

Floor sweeper—many industries have preset, rigid environments. A grocery store with straight, regular aisles lends itself to having robot floor sweepers. The robots could double as security devices.

These few ideas may be viewed by some people as frivolous or expensive, but my criteria for robots are simple:

- Use today's technology, not the future's.
- Make it cheap and easy to replace.
- It is better to have the robot perform a few functions well than many functions poorly.
- Make the robots visually pleasing.
- Make them fun and helpful.

The simplest things in nature work best. Simple robots performing simple tasks are within our current capabilities.

Mike Halverson
National Sales Manager
Link Telecommunications, Inc.
3850 Annapolis Lane
Plymouth, MN 55447

Attention Lispers

I am interested in establishing relationships and exchanging ideas with others working in the field of Artificial Intelligence. My experience is limited, using an IBM PC with muLISP-83, but my intention is to continue to explore AI especially where it can be applied to corporate and commercial uses. I would like to hear from anyone with similar interests.

Kevin A. Curtis
81 Columbia Ave
Hopewell, NJ 08525

Avnet Address

Help! In the Hayden Books collection of *Robotics Age* reprints, "In the Beginning," page

174 contains plans for a "robot digestive tract." The parts list refers to a General Instrument Optoelectronic Type-400 AC line monitor, powered to logic opto-isolated interface IC. The article states that the chip is available from Hamilton Avnet. Could you please tell me how to contact these people?

Chois Blackwell
306 Webb
Waco, TX 76705

Hamilton Avnet can be reached at 50 Tower Office Park, Woburn, MA 01801. General Instrument is located at 600 W. Johns St., Hicksville, NY 11802.

Purdue Course

A list of schools and colleges offering courses and/or programs in robotics or robotics-related subjects was listed in the January 1984 issue of *Robotics Age*. This article also stated that the information was obtained from a RI/SME directory.

Would you please let me know what the procedures are for getting listed in the directory? Our school received an SME grant in 1982 and obtained a Mini-Mover 5 and some course development funds from SME. We started our first Robotics Applications Course, MET-365, using Joseph Engelberger's book "Robots in Practice" as a text. The course is a 3 credit hour course with two hours of lecture and two hours of laboratory work on learning to program the robot with the Apple II computer. We have three Mini-Mover 5 robots in our laboratory backed up by three Apple II computers.

The course is required in our Manufacturing Engineering Technology degree program and an elective in any of our other degree programs within the School of Technology. We believe that we are one of the first units in the Purdue system to provide an undergraduate course in the robotics field.

I would appreciate any information about the listing which you can provide.

Professor Donald J. McAleece
CMfgE (Robotics)
Indiana University—Purdue University
at Fort Wayne
2101 Coliseum Boulevard East
Fort Wayne, IN 46805

The directory was published by the Society of Manufacturing Engineers. I do not know if they intend to publish a second edition. The person to speak to is Peter Blake at Robotics Industry Association, Education and Training Division, One SME Drive, PO Box 930, Dearborn, MI 48121.



PERSONAL ROBOTS

Peripherals and Software for Personal Robots

MICROMATION proudly presents a peripheral for HEATHKIT'S® HERO-I robot which elevates the robot to a new level of sophistication. We call this peripheral a Voice Command System (or VCS) because it not only consists of a Voice Recognizer (VOREC), but also an advanced level machine Voice Command Language (VOCOL) program for the robot which allows you to program robot movements by voice. Highlights of these two important parts of the VCS are described below.

VOICE COMMAND SYSTEM FOR HERO

VOREC*

VOREC is a powerful, microprocessor controlled, speech recognition board which mounts next to, and interfaces with, our HERO MEMCOM BOARD. VOREC has the following features and specifications:

- Speaker-dependent recognizer with nearly instantaneous word recognition rates.
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- 16K of onboard static RAM of which 14K is battery backed to retain recognized word parameters during power down.
- RS232 port for receiving commands from, and reporting status and words recognized to, the host (HERO).
- Requires only an external speaker for audio input rather than a microphone. (Allows robot to receive commands from up to 15 feet away.)
- Utilizes high speed (HC) CMOS chips and the new CMOS 65C02 microprocessor for ultra low power consumption. Complete board consumes an incredibly low 45 ma while active and 1 ma when inactive.
- Speech recognition is accomplished by a software algorithm contained in a 2K EPROM. (Future product updates will require only replacement of this EPROM.)

*COMPATIBLE WITH ALL PERSONAL COMPUTERS

The Voice Command System manual contains a complete description of how to use the VOREC board under program control from HERO. The 6808 Source Code for VOCOL is available on an APPLE DOS 3.3 disk. This source code is compatible with the SC-6800 CROSS ASSEMBLER.

TOTAL SYSTEM PRICE: \$595.00

VOICE COMMAND SYSTEM WITH MEMCOM BOARD: \$920.00

HERO MEMCOM BOARD*

The MEMCOM board provides a means to develop programs for the robot using a personal computer, expanding the robot's memory with an additional 30K of RAM. The MEMCOM board includes:

- Two 8-bit bi-directional parallel ports with handshaking lines for super-fast data transfers between the robot and a computer, plus two 16-bit timers.
- An RS232 serial port for two-way communications between the robot and any computer having an RS232 serial port.
- Serial communications software in an onboard EPROM which allows uploading/downloading of programs via the serial port.
- Sixteen 2K RAM chips in sockets so 2K EPROM chips may be substituted, if desired. "Memory Protect" and "RAM Supply" are used for each RAM chip so programs will not be lost when robot enters "sleep" mode.
- A large (2" x 5") wire-wrap area with CPU address, data and control lines, $\pm 5V$, ground, and others readily available. All hardware and cables necessary to mount board on rear door of robot and connect board to the robot's CPU board.
- Complete instruction manual and schematics.

*COMPATIBLE WITH ALL PERSONAL COMPUTERS

PRICE: \$345.00

APPLE-HERO COMMUNICATOR

The communicator board provides the hardware and firmware necessary to implement two-way high speed parallel communication between an APPLE® computer and a HERO-I robot equipped with our HERO MEMCOM board. The S-C MACRO ASSEMBLER and 6800 CROSS ASSEMBLER provide the software support necessary to develop programs for HERO. The Communicator board includes:

- A peripheral card for an APPLE that contains two 8-bit parallel ports with handshaking lines, and two 16-bit timers.
- A ribbon cable assembly (5 feet long) for connecting the parallel ports on the card to those on the HERO MEMCOM board.
- Data transfer software for the communicator board and the HERO MEMCOM board burned into two 2716 EPROMS. These programs provide ultra fast two-way communications.
- A disk containing heavily commented 6808 and 6502 source codes for the communications software. These source codes are compatible with the S-C MACRO ASSEMBLER and the S-C 6800 CROSS ASSEMBLER available for the APPLE from the S-C SOFTWARE CORPORATION or MICROMATION. Programs developed using the S-C 6800 CROSS ASSEMBLER can be immediately downloaded and run on the robot using this product and our HERO MEMCOM board.

PRICE \$159.00

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Calendar

JULY

9-12 July. 1984 National Computer Conference. Las Vegas Convention Center, Las Vegas, NV. Contact: Trudi Riley, AFIPS, 1899 Preston White Drive, Reston, VA 22091, telephone (703) 620-8952.

Enhancing Creativity is the theme of the twelfth annual NCC. The conference will focus on how the widespread availability of computing resources is altering the office, factory, and home.

23-27 July. SIGGRAPH '84. Minneapolis, MN. Contact: SIGGRAPH Conference Office, 111 East Wacker Drive, Chicago, IL 60601, telephone (312) 644-6610.

This year's SIGGRAPH Conference attendees will be treated to a vast array of technical and exhibit offerings. The program includes up to 30 one- or two-day courses, panels on topical computer graphics issues, a larger number of exhibits, a design arts show, and the premiere of the first totally computer-generated Omnimax film. Presented papers cover ray tracing techniques, graphics hardware, visible surface algo-

rithms, interactive systems, shading and texturing, algorithms for painting and matting, and graphics standards.

30 July-3 August. Robot Manipulators, Computer Vision, and Automated Assembly. MIT, Boston, MA. Contact: Director of the Summer Session, Room E19-356, Massachusetts Institute of Technology, Cambridge, MA 02139.

A short course given at MIT to prepare participants for the sophisticated methods soon to be employed in advanced automation. The emphasis is on developing strategies for the solution of problems in sensing, spatial reasoning, and manipulation. The use of existing industrial robots and binary vision systems is also covered.

30 July-3 August. Robotics: Concepts, Theory, and Applications. University of Michigan. Contact: The University of Michigan, College of Engineering, Engineering Summer Conferences, Chrysler Center, North Campus, Ann Arbor, MI 48109, telephone (313) 764-8490.

Course covers concepts and mathematics of computer-based robots. Topics include kinematics, dynamics and control, robotic vision,

integration of sensor systems, robotic languages, economic justification, and applications. Laboratory sessions using PUMA robot arms illustrate the concepts presented in the lectures.

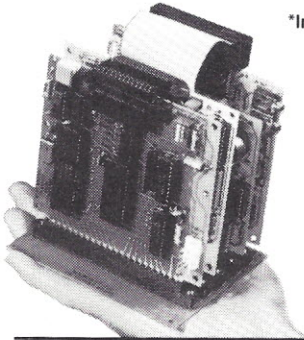
AUGUST

1-3 August. The Computer: Extension of the Human Mind. Eugene, OR. Contact: Summer Conference Office, College of Education, University of Oregon, Eugene, Oregon 97403.

This conference, the third annual computer and instructional technologies conference to be sponsored by the Center for Advanced Technology in Education, will focus on the needs of the individual who has become responsible for school and district level use of computers and other emerging instructional technologies. Both general and special interest group sessions will be supplemented with an extensive vendor hall and film/video theater related to computer technology in education. Pre- and post-conference workshops will be conducted on the educational uses of computers.

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Z8 Serial Expansion Board ..(BCC08) ..	\$160
Z8 BASIC A to D Converter (BCC13) ..	\$140
Z8 BASIC 16K Memory Expansion (BCC15) ..	\$155

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Calendar

5-8 August. Lisp and Functional Programming. University of Texas at Austin. Contact: Robert S. Boyer, University of Texas at Austin, Institute for Computing Science, 2100 Main Building, Austin, TX 78712, telephone (512) 471-1901.

This is the third in a series of biennial conferences on the Lisp language and issues related to applicative languages. Areas of interest include implementation problems; programming environments; large implementations; support tools; architectures; microcode and hardware implementations; significant language extensions; lazy evaluation; functional programming; logic programming; combinators; FP; APL; Prolog; and other languages.

20-24 August. National Conference and Exhibition on Robotics—1984. Melbourne, Australia. Contact: The Conference Manager, Institution of Engineers-Australia, 11 National Circuit, BARTON, A.C.T. 2600, AUSTRALIA, telephone (062) 73-633.

This conference promises to be the most important Australian robotic event held to date. It will have a strong application and education

emphasis. Leading Australian robot users, developers, and researchers will present their experience and views on this important high-technology area.

27-30 August. Adaptive Control—Design and Applications, Course. University of California, Berkeley, CA. Contact: Continuing Education in Engineering, University of California Extension, 2223 Fulton St., Berkeley, CA 94720, telephone (415) 642-4151.

Intensive four-day course intended for professionals engaged in the design and implementation of modern control systems, such as engineers and computer-applications specialists involved in designing real-time monitoring and control systems or in developing control software. Emphasis will be on providing a clear understanding of various adaptive control techniques, including on-line identification schemes, as well as on future trends in system design. Case studies and computer laboratory sessions will supplement course lectures.

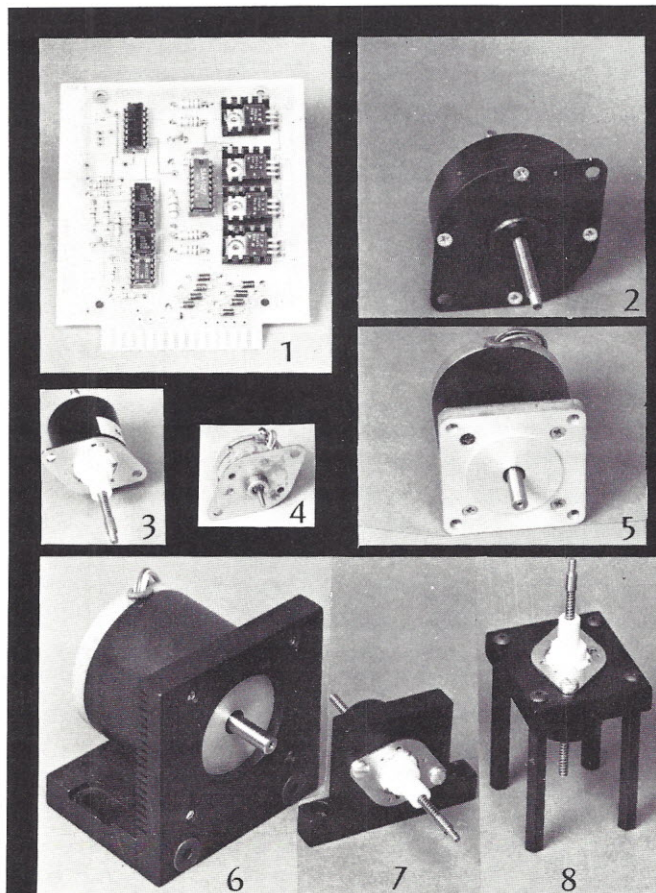
29-30 August. An Applications-Oriented Approach to Artificial Intelligence (Course

994DC). George Washington University, Washington, DC. Contact: George Harrison, George Washington University, Continuing Engineering Education, Washington, DC 20052, telephone (202) 676-6106.

The purpose of this course is to provide an understanding of the design, application, and implementation of an *intelligent* system based on artificial intelligence processing techniques that are directly applicable to the solution of practical problems. The course also discusses how to choose from among the many available options in selecting or designing intelligent systems based on artificial intelligence processing techniques. The program is intended for project and design engineers, scientists, systems analysts, and technical managers who have responsibilities for specifying, designing, and implementing artificial intelligence-based systems.

SEPTEMBER

10-13 September. 10th Annual Advanced Control Conference. Fowler Hall, Stewart Center, Purdue University, West Lafayette, IN. Contact:



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WINTER 1979: Advances in Switched-Mode Power Conversion, Part 1; Prospects for Robots in Space; Robotics Research in Japan, Report from IJCA16.

SPRING 1980: Microcomputer Based Path Control; Robotics Research in France; Multiple Sensors for a Low-Cost Robot; the Robots of Autofact II; Inside Big Trak.

SUMMER 1980: Industrial Robots; Today and Tomorrow; Introducing the Minimover 5; Advances in Switched Mode Power, Part II.

FALL 1980: Using Optical Shaft Encoders; Interview with Victor Scheinman; Robot Vision for Industry; The Autovision System; Industrial Robotics '80; Robots on Your Own Time; Superkim Meets ET-2.

JAN/FEB 1981: A Robot Arm Without a Budget; An Interview with Joseph Engelberger; Robots V—Dearborn 1980; Robots on Your Own Time; Opto "Whiskers," Robot Toy Designs.

MAR/APR 1981: Video Signal Input; Chain-Code; Camera Geometry for Robot Vision; TIG Welding with Robots; Robot Digestive Track—Robots on Your Own Time.

MAY/JUNE 1981: Rehabilitative Robots; A Homebuilt Computer Controlled Lathe; An Interview with Charlie Rosen; Superkim Meets ET-2, Part II.

JULY/AUG 1981: Segmenting Binary Images; The Robot as Transfer Device; Continuous Path Control of Stepper Motors; TIMEL: A Homebuilt Robot.

SEP/OCT 1981: Bullish Days in the Robot Business: Edge Detection in Man & Machine; Continuous Path Control with Stepping Motors; Build a Low-Cost Image Digitizer, Report from JACC-81; The Robot Builder's Bookshelf.

NOV/DEC 1981: Teach Your Robot to Speak; Fast Trig Functions for Robot Control; An Interview with George Devol; The Great Japanese Robot Show; TIMEL: A Homebuilt Robot, Part II.

JAN/FEB 1982: Avatar: A Homebuilt Robot; A Look at SS-50 Computer Boards; Working Within Limits; Amblatron: Another Contest Winner; Quester.

MAR/APR 1982: The Rhino XR-1: A Hands-On Introduction to Robotics; Power for Robots; A Computer Controlled Sentry Robot: A Homebuilt Project Report; Natural Language Understanding: A First Look; RT-13 Video/Sound Recognition System; An Inexpensive Hand; Type 'N' Talk.

MAY/JUNE 1982: Part Sources for Robots; An Inexpensive Arm-Hand System; The Polaroid P100 Polapulse Battery: Solution Waiting for a Problem; New Robot Books for the Bookcase: Applying Robot Vision to the Real World; Robots VI: A Landmark in an Exciting Era; Photo Essay and Notes from Robot VI.

JULY/AUG 1982: The Microbot Teach-mover; Some Notes On the Rhino XR-1 and Minimover 5; Patent Probe; Use Your Apple As a Robotics Development System; IBM Robots; Adapting a Speech Synthesizer; Constructing an Intelligent Mobile Platform, Part I.

SEPT/OCT 1982: Roving Robots; Report on SIG-GRAPH '82; Patent Probe No. 4,221,997; Constructing an Intelligent Mobile Platform, Part II; The Physics of One-Legged Mobile Robots.

NOV/DEC 1982: Robot Wrist Actuators; Patent Probe; A Microcomputer Based, Real-Time Robot System; The Physics of One-Legged Mobile Robots; Part II; 1982 AAAI Conference; Armatron: A Study in Arm Engineering; Invention Documentation: A Primer.

JAN/FEB 1983: The Move-Master RM-101; Mailmobiles in the Office; Teaching the Rhino XR-1 to Write; The Philosophy and Birth of Computer Science; The 2-Roll Gripper.

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JULY/AUG 1983: The Get Away Special, Part I; A Nose for the Heath Hero-1; Patent Probe: Ambulatory Platform; Robotics and the Law: Organizing the Venture; A Table of Contemporary Manipulator Devices.

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NOV/DEC 1983: Complete Control with Forth on a Chip; A Simple Sense of Touch for Robotic Fingers; Current Offerings in Robotics Education; Single Board Computer Manufacturers; A Table of Contemporary Manipulator Devices; Welding Apparatus with Vision Correction.

JANUARY 1984: Robots in Batch Manufacturing; Super Armatron; Directory of Robotics Education and Training Institutions; A Table of Contemporary Manipulator Devices; Patent Probe: A New Robot Patent Category; Operator Roles in Robotics; The Scorpion: Software Overview.

FEBRUARY 1984: GRASP: From Computer Aided Robot Design to Off-Line Programming; Design and Construction of a Five-Fingered Robotic Hand; Patent Probe: Omnidirectional Vehicle; Using Microprocessors with Radio-Control Servos; Designing a Reliable Voice-Input Robot Control Language; Part II, The Scorpion: Motor Control Instructions.

MARCH 1984: Part I, Armega 33: Mechanical Design; Patent Probe: Robot Computer Chess; Part III, The Scorpion: Commands with Responses; A Simple Computer Interface.

APRIL 1984: Closing the Sensor-Computer-Control Loop; Bipedal Balance; Patent Probe: Robot Warehouse; Part II, Armega 33: The Electrical Components.

MAY 1984: Backyard Foundry for Sand Casting; Androtext, A High-Level Language for Personal Robots; Part III, Armega 33: Computer Control; Computers in the Real World.

JUNE 1984: Introduction to Numerical Control Programming; Glossary of CNC and Machine Tool Technology; A Glance at Some Microprocessor-Controlled CNC Tools; Intel's Bitbus Microcontroller Interconnect.

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Calendar

Edward J. Kompass, Control Engineering Magazine, 1301 South Grove Ave., PO Box 1030, Barrington, IL 60010, telephone (312) 381-1840.

This year's conference celebrates the 25th anniversary of the application of digital computers to industrial control. Twenty-two applications papers will support the four specially-commissioned, two-hour tutorials. Topics include: a view of the beginnings and development of computer-based industrial control, the merging of discrete and continuous process control, the beginning of computer-based digital control systems, and a future scenario for computer-based digital control systems. Applications papers cover: array processors, fiber optic data buses, micro and personal computer packaging for industrial applications, personal computer software packages for industrial control, industrial I/O for personal computers and the role of humans in fully computerized industrial plants.

14-16 September. Heart of Texas Computer Show. Bayfront Plaza, Corpus Christi, TX. Contact: Heart of Texas Computer Show, PO Box 12094, San Antonio, TX 78212, telephone (512) 681-2248.

The show features vendors displaying the latest in small business and personal computer systems, with robots, games, and other high-tech products. Educational seminars are also planned.

24-26 September. Robotics Seminar. IEE Education Center, Technology Park/Atlanta, Norcross, GA. Contact: Institute of Industrial Engineers, Conference Department, 25 Technology Park/Atlanta, Norcross, GA 30092, telephone (404) 449-0460.

The Robotics Seminar is designed to acquaint participants with the variety of equipment available and how and where robots might be used effectively. Special seminar features include a full-day laboratory experience where participants can see robots in action and a workshop session for discussing and analyzing potential robot applications.

25-26 September. NASA Symposium on Productivity and Quality: Strategies for Improving Operations in Government and Industry. Capitol Hilton Hotel, Washington, DC. Contact: Pamela Edwards, AIAA, telephone (212) 581-4300.

The symposium is sponsored by NASA and organized and operated by AIAA.

25-27 September. International Industrial Controls Conference and Exposition (IIC '84). Philadelphia Civic Center, Philadelphia, PA. Contact: Tower Conference Management Co., 331 W. Wesley St., Wheaton, IL 60187, telephone (312) 668-8100.

Preliminary session titles include: *Advances in Information Flow Networks; Highways for Factory Automation; Vision; User-friendly Software for Programmable Controllers; Fiber Optics; and Robotics.*

OCTOBER

2-4 October. 14th International Symposium on Industrial Robots. Gothenburg, Sweden. Contact: Swedish Trade Office, 4000 Town Center, Suite 202, Southfield, MI 48075, telephone (313) 352-6990.

Nearly 1,000 delegates are expected to participate in this year's symposium. In connection with the symposium, there will also be an extensive international exhibition showing the

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Calendar

latest developments and achievements in the field of industrial robots.

2-4 October. AUTOFACT 6. Anaheim Convention Center, Anaheim, CA. Contact: Gregg Balko, Computer and Automated Systems Association of SME, One SME Drive, PO Box 930, Dearborn, MI 48121, telephone (313) 271-1500.

AUTOFACT 6 will feature a comprehensive program of tutorials and conference sessions covering the entire spectrum of computer-integrated manufacturing—from design and engineering, through fabrication, assembly, inspection and testing, to shipping.

2-5 October. Robot 84, Scanautomatic 84, and The 14th International Symposium on Industrial Robots. Gothenburg, Sweden. Contact: Swedish Trade Fairs Foundation, Box 5222, S-402 24 Goteborg, SWEDEN, telephone 46 31 20 00 00.

Three major international events devoted to the design, production, and uses of industrial robots will take place in the Swedish Trade Fair

halls simultaneously in October. Robot 84 is an international exhibition of industrial robots and control systems for materials handling, assembly, and complex production tasks. Scanautomatic 84 covers industrial computers and the pneumatic, hydraulic, and electronic components which provide the backup technology for industrial automation. The Symposium on Industrial Robots is organized jointly by the Swedish Trade Council, the Swedish Trade Fairs Foundation, and MEKAN, Sweden's largest industrial association.

ACM-84, The Fifth Generation Challenge. San Francisco Hilton, San Francisco, CA. Contact: ACM-84, PO Box 32575, San Jose, CA 95152, telephone (415) 948-6306.

The Japanese Fifth Generation supercomputers pose a challenge to American computer manufacturers. The ACM-84 Conference topic areas attest to the concern about the Japanese challenge: supercomputers; developments in artificial intelligence; robotics and sensing; the impact of the fifth generation; limits on technology transfer; applications for the 1990s in

business, education, manufacturing, research, and the professions; and anticipated changes in society.

10-12 October. InteRobot-West '84. Long Beach Convention Center, Long Beach, CA. Contact: Tower Conference Management Co., 331 W. Wesley St., Wheaton, IL 60187, telephone (312) 668-8100.

InteRobot-West '84 offers 20 technical conference sessions, three special-interest tutorials, and 80 internationally recognized speakers and session chairmen. Session titles include: *Industry Overview; Tooling Design; Machine Languages; Machine Vision; Machine Sensors; Robots in the Foundry; Personal and Educational Robots; Education in Robotics; and Emerging Robot Applications.*

25-27 October. Robotics Seminar. IIE Education Center, Technology Park/Atlanta, Norcross, GA. Contact: Institute of Industrial Engineers, Conference Department, 25 Technology Park/Atlanta, Norcross, GA 30092, telephone (404) 449-0460.

The Robotics Seminar is designed to acquaint participants with the variety of equipment available and how and where robots might be used effectively. Special seminar features include a full-day laboratory experience where participants can see robots in action and a workshop session for discussing and analyzing potential robot applications.

NOVEMBER

4-9 November. Intelligent Robots and Computer Vision. Hyatt Regency, Cambridge, MA. Contact: SPIE—The International Society for Optical Engineering, Bellingham, WA 98227-0010, telephone (206) 676-3290.

The emphasis for the 1984 conference is intelligent robots, vision, and sensor systems. The intent of the sessions is to address and interchange ideas on a wide range of applications, issues, and techniques for these advanced intelligent systems. State-of-the-art technical design and modern equipment concepts will be presented. Topics to be addressed and for which contributed papers are requested include: government and industrial programs in intelligent sensors and robotics; applications of intelligent sensor systems; statics, kinematics, dynamics, and control of robot systems; standards for sensors and robots; image processing; feature extraction; three-dimensional object representation; use and application of artificial intelligence; and image understanding in intelligent robotics and computer vision.

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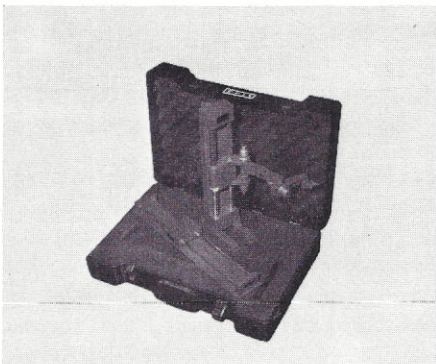
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TURTLE MOTORS. Attention, Terrapin Turtle owners: if you're looking for spare Turtle parts, you should get in touch with Patrick Stakem at Interface Technology, Inc. Pat has purchased all of Terrapin's hardware stock and is repairing their turtles. The stepper motors are selling for approximately \$35. The motors appear suitable for many different drive applications. Interface Technology, Inc. is at Box 745 College Park, Maryland, 20740, telephone (301) 490-3608.

ROBOTS BY MAIL. Rio Grande Robotics is claimed to be the first mail order firm in the US devoted exclusively to personal robotics. They have signed national distribution agreements with RB Robot Corp, Iowa Precision Robotics, Excalibur Technologies, and various kit manufacturers. Dealer agreements with other manufacturers are in preparation. The firm's personnel have extensive experience in micro-computer training. In addition to the robot and robot-related hardware, Rio Grande Robotics

plans to handle educational software.

Rio Grande Robotics is located at 1595 W. Picacho #28, Las Cruces, NM 88005, telephone (505) 524-9480.

MARK YOUR CALENDAR. Make your arrangements early for the 19th International Symposium and Exposition on Robots, to be held in Sydney, Australia in 1988, as part of Australia's national Bicentennial celebrations. It will be the first time the International Symposium on Industrial Robots has been held outside of the USA, Western Europe, or Japan. More than 1,000 delegates from home and overseas will attend the November Symposium at Sydney's Hilton Hotel. Thousands of people will have the opportunity to explore the world of robot technology at the concurrent Exposition.

For more information, contact Ellen McArthur, Information Officer, The Australian Bicentennial Authority, GPO Box AUS 1988 Sydney 2001, telephone (02) 236 1988.

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Sensory Perceptions



POUR ME ANOTHER TEQUILA. Scarab Robotics believes the time for the automated bartender has arrived. The Scarab X-1 "robotic bar" is housed in a gleaming 10 by 8 ft. oak cabinet and can hold 36 standard 1.75 liter liquor bottles, a half keg of cold beer, chilled white wine, red wine, and standard mixers. Although the \$65,000 price tag is beyond what many homeowners will wish to pay for personal enter-

tainment, the robot bar is expected to be a profitable attention grabber in hotel and casino bars. The bar is claimed to be voice actuated, allowing waiters and waitresses to order drinks via wireless FM transmitters, and have the drinks waiting by the time they reach the bar. The Scarab comes complete with an Apple II computer and Votan voice I/O system.

RSA CHAPTERS. The Robotics Society of America has published a list of chapter contact people. The following people can provide information about meeting times and locations. Rick Refuerzo, telephone (415) 945-6357, is the contact person for the Berkeley Chapter. Steve Zonis, telephone (213) 934-0522, and Bruce Sanchez, telephone (213) 470-8383, can provide information about the Los Angeles Chapter. Kevin Mullins, telephone (415) 494-5079, has dates and times for the Palo Alto Chapter. Jim Strobe, telephone (415) 552-6564, is the contact person for the San Francisco Chapter. Walt Carter, the San Jose Chapter contact, can be reached at (408) 986-8686. Readers interested in the Southern Illinois Robotics Association Chapter can contact Doug Wall at (618) 226-3478.

To find out if there is an RSA Chapter being formed near you, contact: Walter Tunick, Robotics Society of America, 200 California Ave, Suite 215, Palo Alto, CA 94306.

AI NOW. A recent study conducted by Brattle Research Corporation states that the commercial impact of artificial intelligence research will occur "far sooner than commonly predicted." The last two years has seen "a groundswell of interest in artificial intelligence by a broad spectrum of corporations." The report expects the appearance of super microcomputers and special processors for AI software to accelerate the transfer rate of AI technology to the commercial sector.

The study also reports on the state of artificial intelligence programming languages. It concludes that machines that can run Lisp "provide a level of software and data base integration that is unobtainable with conventional hardware and software." Lisp workstations are claimed to increase programmer productivity thirtyfold and allow computers to solve a whole new class of problems. The market for Lisp machines and pure AI applications is predicted to break \$1 billion by 1988.

The report, entitled "Artificial Intelligence Computers and Software: Technology and Trends," is available from Brattle Research Corp., Athenaeum House, 215 First St., Cambridge, MA 02142, telephone (617) 492-1982.

CELESTIAL ANALYSIS. "Engineers need software too," is the slogan on Celestial Software's promotional buttons. The design software provided by Celestial is a tool useful for mechanical design engineers, civil engineers, and architects. IMAGES-2D is a finite-element analysis program which helps engineers design mechanical structures. The component under analysis is displayed in full-color, high-resolution graphics on IBM PC and DEC microcomputers.

The software is comprised of three major sections: Geometry Definition, Static Analysis, and Dynamic and Seismic Analysis. The Geometry Definition portion provides a simple method for defining modes and elements. A full geometry checking feature identifies such items as unconnected nodes and undefined material or cross-sectional properties. Static Analysis allows you to determine the response to any static loads including deadweights, imposed external loads, and thermal expansion. IMAGES-2D summarizes stresses, loads, and reactions in a highly readable report format. Deflected shapes can be plotted and exaggerated for closer inspection. The software can handle up to five simultaneous loads.

One of the most impressive capabilities is the use of seismic analysis to determine elastic structural response due to any user-defined shock. This ability has formally been available only on much larger computers. The structural response can also be animated to provide a visual representation of the dynamic and seismic analysis.

For more information about IMAGES-2D, contact: Celestial Software, Inc., 125 University Ave., Berkeley, CA 94710, telephone (415) 841-7175.

HIGH-SPEED COMMUNICATIONS. American Robot Corp. is developing a high-speed communications interface which is designed to allow robot-to-host-computer communication rates up to 10 times faster than current interfaces. The high-speed interface will be used with the National Bureau of Standard's new Automated Manufacturing Research Facility (ARMF) in Gaithersburg Maryland. The interface will allow communication rates up to 500 Hz and permit robots, vision systems, and host computers to work together in real-time environments. The interface is due to be released in the second quarter of 1984.

SHAPE MEMORY EFFECT ALLOYS FOR ROBOTIC DEVICES

Dr. L. McD. Schetky
Memory Metals, Inc.
PO Box 2518
652 Glenbrook Road
Stamford, CT 06906

Robots of great versatility are now available from manufacturers in Japan, North America, and Europe, with dexterity and lifting capacity which a decade ago would have been considered difficult, if not impossible, to achieve. The major advances in recent years have been in the area of microprocessors, servo systems, programming, and optical sensors for pattern recognition and path tracing. In all these robot devices, whether for heavy or light work, for fixed sequence operation or variable programming, the muscle which moves the arms, elbows, wrists, grips, and fingers is provided by hydraulic, pneumatic, and electric motors. Although these motors offer high speed, good reliability, and an ability to move and lift substantial weights, the drives are relatively large.

A new actuator has been developed which offers exciting possibilities for miniaturizing the robot, making possible units which can propel themselves into currently inaccessible places, work in hazardous environments, and by their much

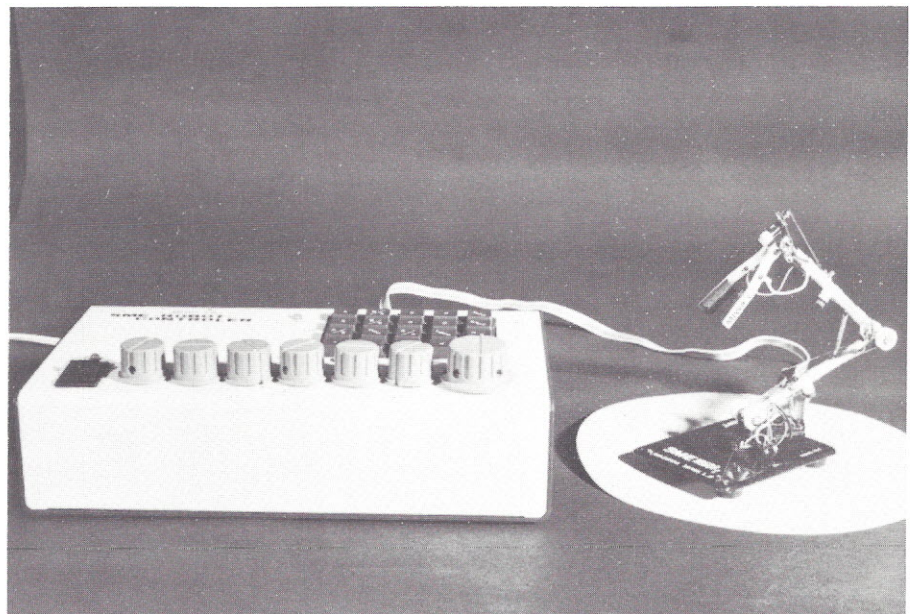


Photo 1. A robotic gripper using shape memory effect alloy actuators. The controller is shown on the left.

lower weight and smaller size offer the possibility of five-finger dexterity.

The basis for this new force-motion transducer lies in a recently exploited

phenomenon known as the shape memory effect.

In essence, a part deformed or stretched at one temperature will, upon being heated to a second temperature, completely recover its original shape. Through appropriate heat treatment, the part can be made to spontaneously change from one shape to the other when cycled between two temperatures. In the process, the moving metal delivers substantial force.

Shape memory is a behavior unique to alloys which undergo what is referred to as a *martensitic* transformation. This is the transformation in crystal structure which occurs in the heat treating of steels to give them hardness and strength. In shape memory, the martensite, unlike the martensite in steel, is thermoelastic; that is, it continually appears and disappears with falling and rising temperatures.

A specimen in the martensitic condition may be deformed in what appears to be a plastic manner, but is actually deforming as a result of a growth and shrinkage of individual martensitic plates. When the specimen which has been deformed is heated to the temperature where the martensite structure changes to the stable elevated temperature crystal structure, a complete recovery of the deformation takes place. Though the specimen must be heated to a relatively high temperature and then quenched to form the initial martensite structures, the metal can revert to the parent structure with only moderate heating. A typical transformation temperature range for copper base memory alloys is 20°C.

The temperature at which martensite starts to form on cooling from the parent phase temperature is called M_s . The temperature at which the entire parent crystal is converted to a martensite cluster is M_f . When the alloy is heated to reverse the reaction, the initial parent phase starts to reform at A_s and is completed at A_f . This is illustrated in figure 1. The parameter that determines the working temperature range of an SME device is composition. In the case of Nickel-Titanium (Ni-Ti) alloys, the usual composition is in the region of 50-50 atomic percent of the two elements.

The point at which martensite forms (M_s) is extremely sensitive to variation in the Ni-Ti ratio. The M_s can be varied from -200°C to +100°C in these alloys. The other alloy systems which have been ex-

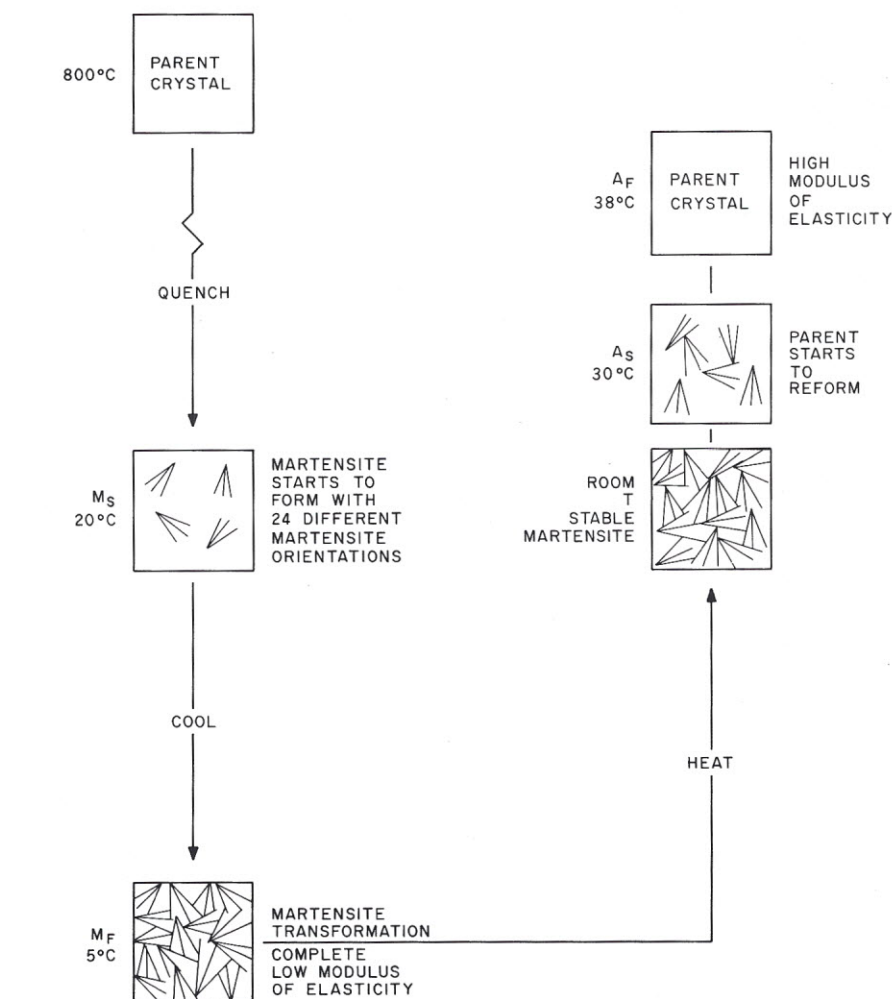


Figure 1. Stages for producing the shape memory effect in a copper alloy. The component is formed to the desired shape, and then heated and quenched to produce martensite crystals. This shape can now be deformed, up to the strain limits. As the component is heated, the parent crystal starts to reform and the original shape is regained.

ploited for a very broad range of applications are the Cu-Zn-Al and Cu-Ni-Al ternaries. The M_s of these alloys can be varied from -105°C to +170°C although a range of -100°C to +60°C is the more acceptable limit for long-term stability. Other additions to this system which have been employed to yield special properties include Sn, Mn, Si, and Ni. Copper-nickel-aluminum alloys exhibit transformation temperatures as high as 200°C. The amount of deformation or recoverable strain varies with the alloy system and for one-way memory typically is 3 percent to 4 percent for copper alloys and 6 percent to 8 percent for nickel-titanium alloys.

Two manifestations of memory can be observed, a *one-way* memory effect and a *two-way* memory. In the former, a part which has been heat treated to yield the

martensite structure may be deformed up to the strain limit. This new shape is retained until the part is heated to the temperature at which martensite transforms to the elevated temperature stable structure. When this occurs, the alloy reverts back to the originally formed shape. Further heating or cooling does not produce any further change.

Producing a part with two-way memory requires a special heat treatment procedure. The component is formed to its initial shape, then heated and quenched to produce martensite. The component is then deformed to its second shape and then cycled between the lower temperature where martensite is stable to the temperature where the parent crystal structure is stable, usually a matter of 30 or 40°C. At the same time that the part is thermally

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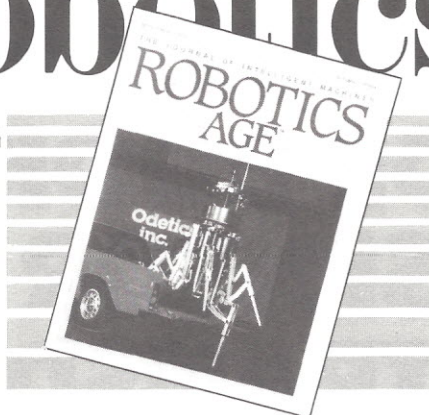
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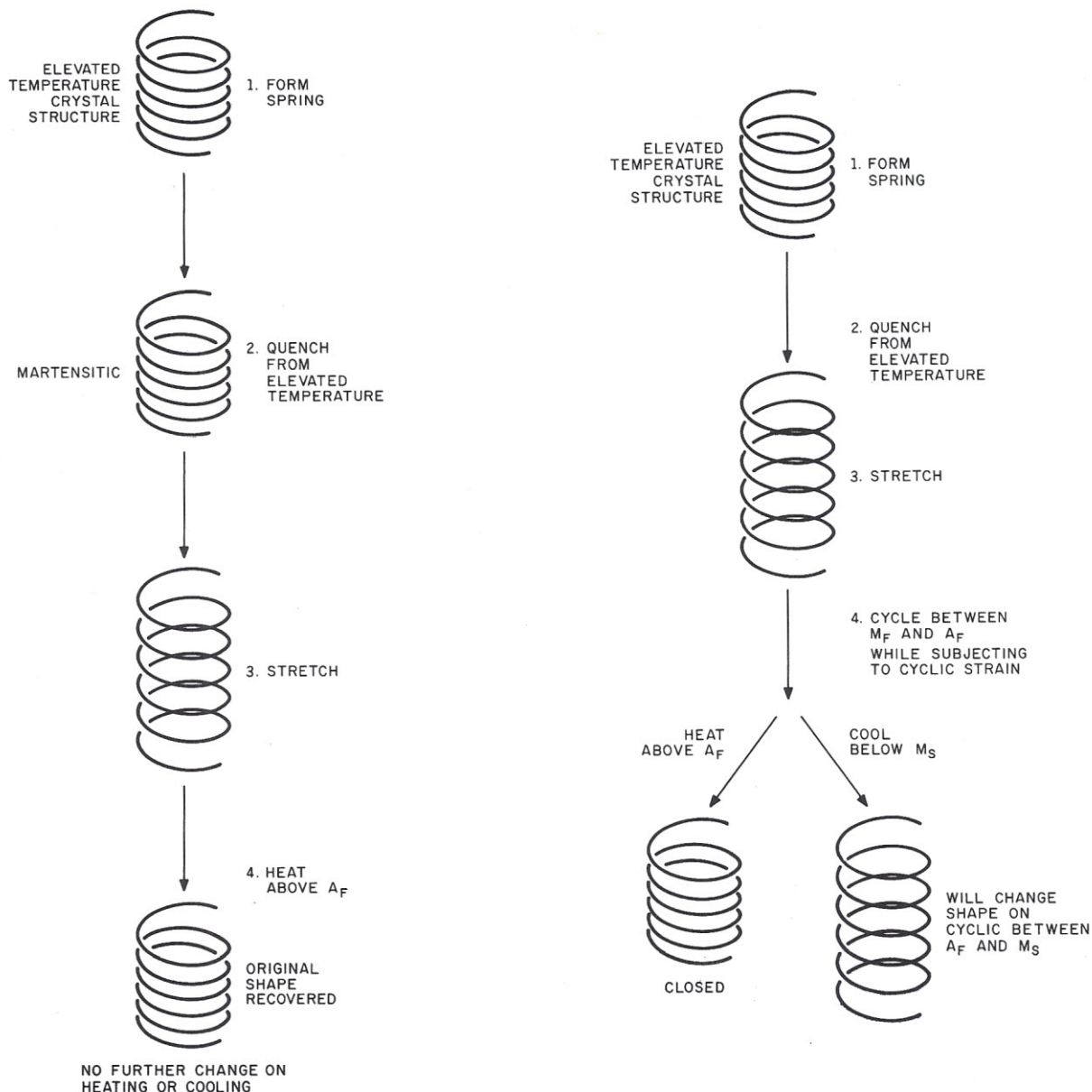


Figure 2. Shape memory can be demonstrated as one-way and two-way memory. One-way shape memory allows a previously formed component to be deformed and then heated. When heated, the original shape is regained. Two-way shape memory cycles between two shapes depending on whether the component is heated or cooled.

cycled, it is subjected to a forced deflection or strain. After many such thermal-mechanical cycles the part will spontaneously assume one shape at the elevated temperature and its second shape at the lower temperature. These two forms of the shape memory effect are illustrated in figure 2.

SME CONTROL

Although most actuators are used in thermostatic devices which must respond to a change in ambient temperature, there are others where the memory effect is required

on demand. As an example, a safety device which is activated by an ambient temperature condition may also be remotely activated by electrical heating. This mode of shape memory energizing is of particular interest for robotic drives.

One of the pioneering efforts in the field of shape memory effect (SME) robot devices is credited to Dr. Yoshiyaki Miwa, who is a professor at Waseda University in Japan. An ingenious wire skeleton was constructed in the form of a four-legged insect with legs driven by SME wires. By phasing the electrical heating of each leg by microprocessor, the insect can be made

to hop across a flat surface. More recognizable as a robot is a table model unit developed by Dr. Miwa which, under processor control, can carry out micromanipulations of the kind required for small parts assembly. With five degrees of freedom, it is capable of accurate motions. Standing less than one foot high, this device illustrates the substantial reduction in size that is possible with SME actuators. Professor Miwa feels that for an equivalent load capability, on the average, an SME robot arm will have one-tenth the weight of a unit with conventional servomotor drives.

SME drives can be formed in several different shapes: sheet, rod, tube, and wire. Although motions can be in torsion, extension, compression, and bending to accommodate various joint and hand requirements, the most efficient drive on the basis of watts/foot-pound is a wire operating in tension mode.

In considering SME for a robotic motor, Memory Metals, Inc. is presently heavily prejudiced in favor of the nickel-titanium family since these alloys combine high force capability, good corrosion resistance, and high resistivity. This means that the memory effect can be energized with reasonably low currents. On the other hand, the higher thermal conductivity of the copper SME alloys may make it possible to achieve faster cycle times, depending on the drive geometry.

With a yield strength of 60,000 psi (413 MegaPascals) a 0.010 in. (0.25 mm) diameter nickel-titanium wire can support a load of 4.7 lbs (19.8 N), and a 0.020 in. (0.5 mm) diameter wire can support 18.8 lbs (83.6 N). Critical to robotic systems, however, is not just load but inertia. Since SME actuators have very low mass in comparison to hydraulic pistons and motor armatures, the actuator can react very rapidly.

Both heating and cooling are exponential and a function of the ambient temperature and the thermal diffusivity of the alloy. For the alloys discussed, the time constant, θ , which depends on wire composition and shape, may be represented by the equation:

$$\theta = Kd^n$$

where d is the wire diameter, and K and n are a function of the alloy. The time which a wire takes to heat to a temperature T above the ambient temperature T_a is given by the expression:

$$t = \theta \ln \left[\frac{1}{1 - \frac{(T - T_a)}{T_o}} \right]$$

where T_o is the maximum temperature the memory wire would reach when heated by a current. The memory effect actually takes place well before the maximum temperature is reached. The cooling time is expressed by a similar equation:

$$t = \theta \ln \left[\frac{1}{\frac{(T - T_a)}{T_o}} \right]$$

when

$$\theta \ln \left[\frac{1}{\frac{(1 - t - T_a)}{T_o}} \right]$$

where T represents the temperature from which cooling starts, usually the upper transition temperature A_F for complete shape recovery.

Most actuators will cycle between the martensitic state and the elevated temperature parent crystal structure. If cycling is continuous the cycle time can be expressed by:

$$C t_o = \theta \ln \left[\frac{\frac{T_o}{T_{AF}} - 1}{\frac{T_o}{T_{MF}} - 1} \right]$$

This total cycle time is independent of the ambient temperature, although for a given ambient the heating and cooling times themselves will vary.

Since the heating and cooling time varies with the amount by which the transformation temperature is above or below the ambient, it follows that low transition temperatures favor faster heating time. However, if the martensite transformation is below ambient, some type of cooling system must be employed. Since the dominant factor in determining speed is the time constant θ , which is exponentially related to wire diameter, a cluster of smaller diameter wires will act faster than a single wire of the same capacity. As an example, a 0.010 in. (0.25 mm) wire with a 5 lb. (22.2 N) lift capacity has a characteristic time constant of 3.15. A collection of 27 0.002 in. (0.05 mm) wires would have an equivalent load capacity but would have a characteristic time of 0.188, 16 times faster in response. The cluster of wires would, of course, have a considerably larger total cross-section since, to take advantage of the small cross-section wire, the spacing between wires would have to accommodate convective air flow.

The power required to heat the wire to its transformation temperature can be calculated by:

$$P = K(T_{As} - T_a)d^n \text{ milliwatts/inch length}$$

As an example, a 0.010 in. (0.25 mm) diameter Ni-Ti wire 10 in. (25.4 mm) long would lift 4.7 lbs (20.9 N) a distance of 0.8 in. (20.3 mm) with approximately 1.4 W.

This is considerably lower power than would be required by a solenoid of equal lifting capacity.

Although for simplicity we have referred to single or multiple strands of SME wire as robotic drives, in some cases the extension required is far greater than can be accommodated by the elongation of a straight wire. In this case a coil or spring may be used with a typical extension of six times. The force which can be developed is still a function of wire diameter since the SME alloy is a strain-limited device.

An alternative geometry, particularly useful for rotation is a torsion tube. The strain limit of 8 percent would allow up to 100° rotation for a 10 in. (250 mm) long, 0.25 in. diameter (6.25 mm) rod. By using a tube with internal fluid or air cooling, the speed of motion may be improved.

In all of the discussion on electrical actuation it has been assumed that the transformation of martensite to parent, which gives rise to a large increase in elastic modulus, occurs on heating and cooling at a modest rate. Recent work by Miwa and his group have shown that the heating rate has a substantial effect on the recovery stress. Measurements of the recovery of a shape memory wire which had been prestrained 2 percent showed that at a recovery temperature of 77°C, a Ni-Ti wire heated at 15°C/sec gave a recovery stress of 220 MegaPascals; when heated at 34°/sec this increased to 260 MPa; and that a heating rate of 100°/sec showed a recovery stress of 375 MPa, an increase of 70 percent.

The implication drawn from this work is that controlled currents can be exploited to change the response and the starting torque of an SME-driven robotic element. It must be born in mind that very precise control is necessary in order to avoid a temperature overshoot which would lead to degradation of the SME device.

Of concern to the robot system designer is the manner in which an SME command signal is transferred to the robot actuator. The mechanical motion $f(x, y, z, t)$, produced is proportional to the power coupled into the SME actuator which, as we indicated before, can be in the form of a wire, spring, or other configuration capable of being heated by an electric current. Typically the general form of these systems is as shown in figure 3.

The motions which might be required are considered as wave forms of the type

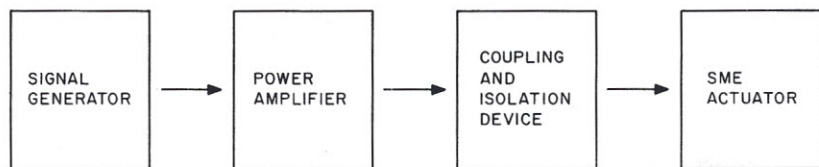


Figure 3. A typical SME actuator control system consists of a signal generator (possibly microprocessor-controlled), power amplifier to boost the signal, and coupling and isolation circuitry to physically connect to the SME actuator.

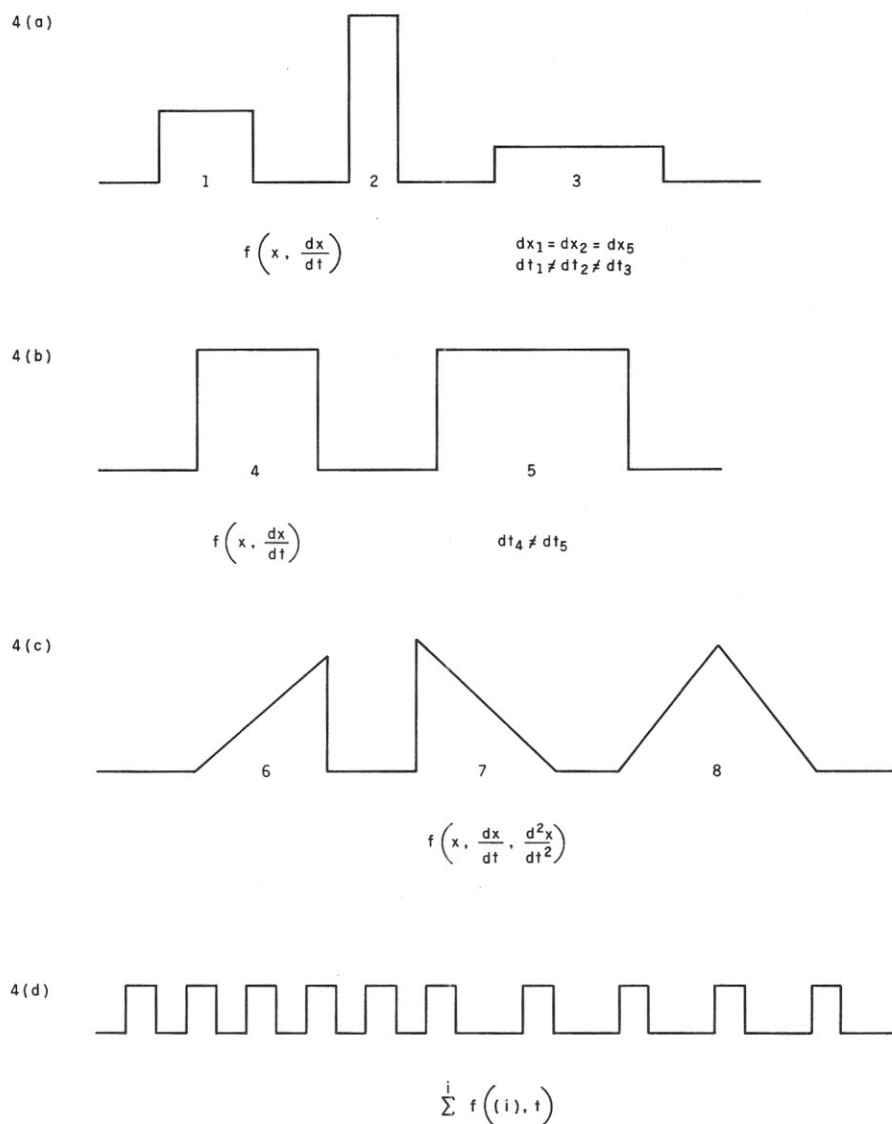


Figure 4. Four different types of signals which can be used to control the SME actuator. Figure 4a shows three signals which will produce the same amount of movement, however, the application of differing currents produces the effect in varied amounts of time. The two signals in figure 4b produce movement proportional to the amount of time the signal is applied to the actuator. Figure 4c demonstrates acceleration, deceleration, and acceleration and deceleration signals. Figure 4d demonstrates a digital method of control. The more rapid the pulses, the greater the heating affect and therefore the more motion exhibited by the shape memory alloy.

shown in figure 4. In figure 4a the total distance traveled is the same for each pulse. However, the time required to achieve the distance varies. In comparison to the first pulse, the second pulse applies more current in less time and the third pulse applies much less current for an extended time to achieve the same motion. In figure 4b the travel distance and time are directly proportional to the pulse amplitude and duration, while in figure 4c the wave shapes produce accelerated and decelerated motion.

In order to obtain more precise accelerations and the higher force which accompany a rapid heating rate, while at the same time avoiding the possibility of overheating, a digitally controlled current input is preferred. Here, in figure 4d, is shown a fast start motion followed by a smooth slow down.

Whether or not the servo is closed loop with feedback will depend on the use of motion, force, or position sensors. Although magnetic changes do occur in nickel-titanium alloys when they undergo strain or shape recovery, these effects are not sufficiently well understood to exploit them as a feedback signal.

CONCLUSION

New shape memory alloys are being developed to power a new generation of robots. The goal is higher recoverable strains, a reduction in hysteresis, good long-term stability, and the development of techniques to increase the cooling rates to make possible faster motions. New copper base shape memory alloys demonstrate good potential with reasonably low cost. A very active effort is going on in Japan, through government sponsorship of a shape memory research and development association. In this country, Memory Metals, Inc., in collaboration with several universities, is carrying out research on new alloys and new actuator geometries. Similar efforts are under way in other US companies and Europe.

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HITACHI'S ROBOT HAND

Yoshiyuki Nakano, Chief Researcher
Masakatsu Fujie, Senior Researcher
Yuji Hosada, Researcher
Mechanical Engineering Research Lab
Hitachi, Ltd.

Hitachi, Ltd. has used a shape memory alloy (SMA) to develop a compact experimental robot hand that can manipulate an object with the dexterity of the human hand.

The recent rise in the demand for advanced automation of various operations, such as delicate assembly work in factories and complicated maintenance work in

special environments like nuclear power plants, has made dexterous and compact robots increasingly desirable.

A number of previous research projects attempted to develop a robot hand capable of simulating the human hand. Developers quickly realized that a large number of actuators would be required to simulate the human hand's fluid joint movement. This,

in turn, would produce an oversized and ungainly mechanism.

Hitachi overcame this problem by using actuators made of SMA. Shape memory alloy is capable of generating a very large force per unit of weight. The structure of these new SMA actuators is less complex than previous actuators that used motors. This reduction in complexity allowed the

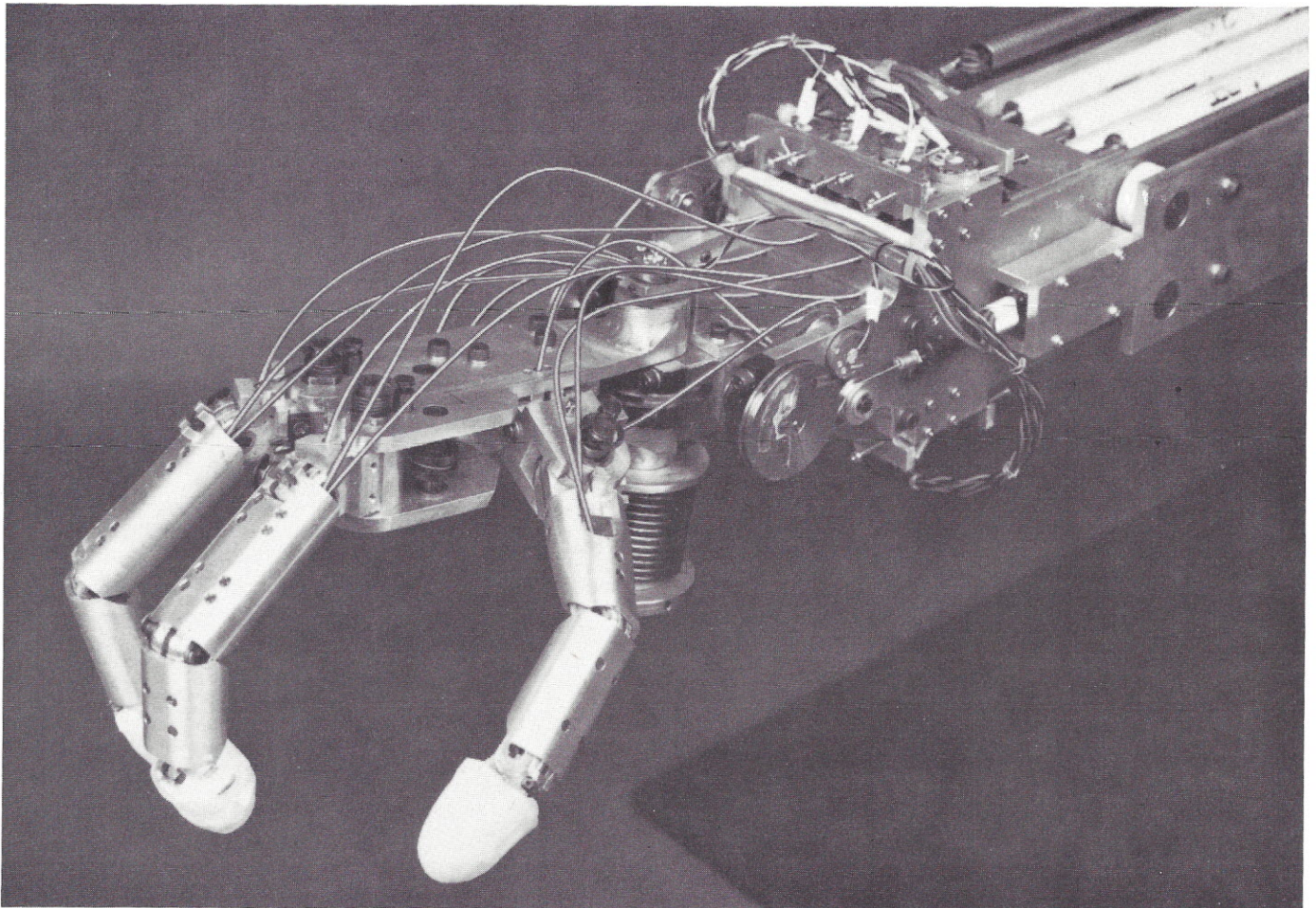


Photo 1. Overview of the Hitachi Shape Memory Alloy gripper.

volume and weight to be reduced to one-tenth that of previous technologies.

The structure of the robot hand is shown in figure 1. The hand has a human-like wrist and three fingers which represent the index finger, middle finger, and thumb of the human hand. Each finger has four joints, which enable the hand to grasp objects firmly. The wrist has two joints for vertical and horizontal movement.

All of the actuators used to drive the hand's joints are built into the forearm. The fingers are driven by 12 actuators (four per finger) and the wrist is driven by two actuators that are set at the side of the forearm. Each finger joint is bent by pulling the drive wire and is relaxed by a spring set into each joint. The wire is guided to the joint through a flexible tube.

The hand and forearm together measure 700 mm in length and weigh 4.5 kg. The block of actuators, weighing a mere 1.5 kg., is 400 mm long, 80 mm wide, and 50 mm high. The actuators can manipulate an object weighing a maximum of 2 kg.

The actuator structure is shown in figure 2. Each actuator consists of SMA wires

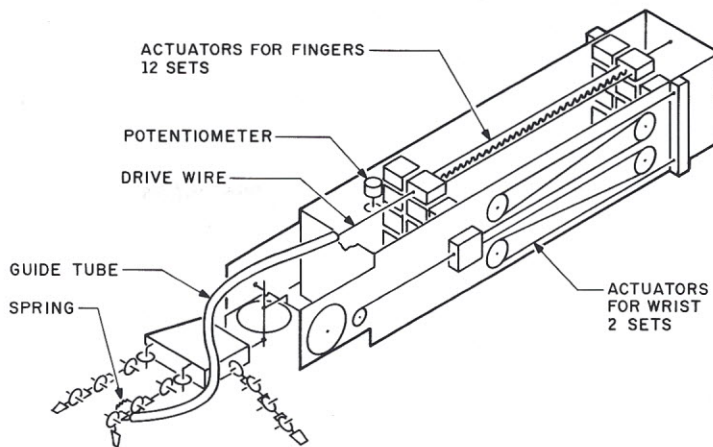


Figure 1. Robot hand structure showing the actuators and guide tubes. A spring around each joint pulls the joint and SMA wire back to the relaxed position.

made from nickel and titanium. Although the SMA wires are pulled and stretched by the springs, they "memorize" their original unstretched length. When they are heated, they tend to shrink back to their original length.

The SMA actuator movement is based on temperature. Since it is difficult to create a rapid temperature change, typical SMA actuators have had a slow response time.

Hitachi dealt with this problem by us-

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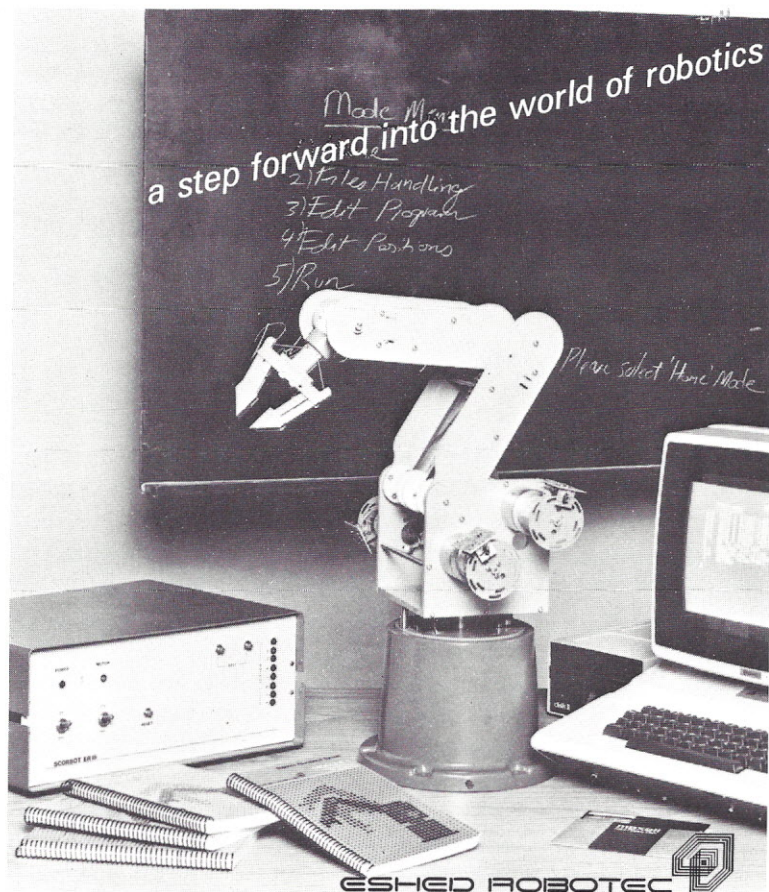
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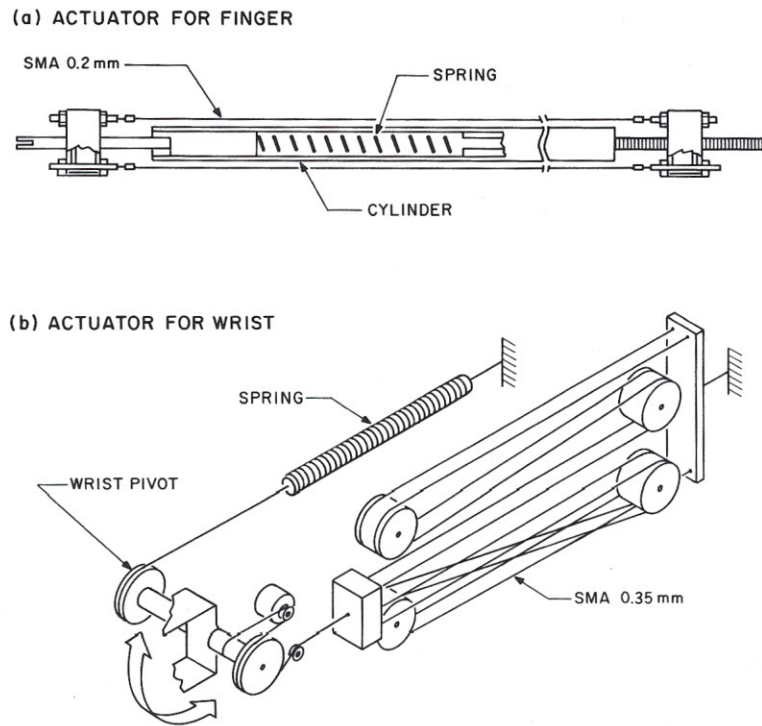


Figure 2. Actuator structures for the finger and wrist.

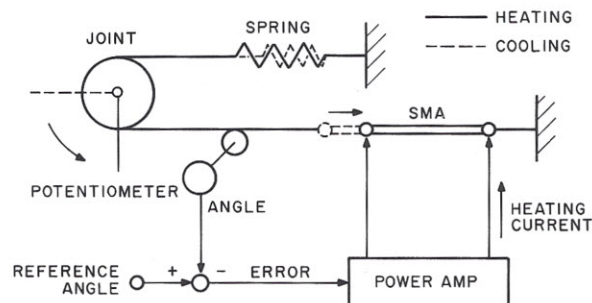


Figure 3. Control system structure.

ing a large number of very thin SMA wires that can be quickly heated and cooled. A number of SMA wires (0.2 mm in diameter) are set around the finger spring actuators (figure 2a). The wrist actuators (figure 2b) each have four SMA wires (0.35 mm diameter) set around the pulleys. Using this technique, Hitachi has achieved a 90-degrees-per-second joint bending motion.

The structure of the hand's control system is shown in figure 3. The SMA wire is heated by passing electric current through it; it reacts by shrinking back against the force of the spring. The joint angle is varied by modulating the current passing through the SMA wire. The current is proportional to the error between

the reference angle and the angle of the joint, as detected by a potentiometer set on each actuator. A microcomputer generates the reference angle values.

The compliance of the SMA actuators and the independent control of each joint allows Hitachi's robot hand to move with human-like flexibility and dexterity.

The development of this lightweight, compact, and dexterous robot hand greatly increases the potential for widespread use of robots and the automation of complex work currently dependent on human hands—whose simulation previously required special jigs or peripheral instruments.

The simple design and compact size of SMA actuators will allow their use in many

applications, such as in medical micromanipulators, handling robots for semiconductors, manipulators for underwater operations, and many others.

For more information about the Hitachi gripper, contact: Dave Tsubota, Gray Consulting Group, Inc., 460 Park Avenue, New York, NY 10022.

Reader Feedback

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71	81	91
Excellent	Good	Fair

Backyard Foundry for Sand Casting

Part II: Making the Molds

Charles Balmer, Jr.
929 S. Dugan Rd.
Urbana, OH 43078

Part I described how to build a backyard foundry for sand casting. By now you have a working furnace and/or an interest in making patterns, molds, and castings. This article shows you how to complete the next phase.

PATTERN MAKING

A pattern is a duplicate of the desired part, but generally made of material that is easily worked and readily available. Pattern materials can vary widely, depending on the desired complexity, frequency of use, ease of construction, and many other parameters.

Patterns can be made from materials as soft and delicate as wax or as strong and hard as steel. Ease of construction far outweighs durability as a criterion for pattern material selection. Patterns of pine are generally easy to make, and with the proper finish, last for a long time.

Patterns must be designed so that after the sand has been packed in the mold parts can be separated without destroying the mold cavity. If the part is very complicated, the mold may require two or more parting lines in order to separate it. If you see that the mold needs more than three parting surfaces, you probably ought to take a different design approach. Photo 4 shows many useful shapes requiring only one parting line that are used in the construction of my robot, Avatar.

Another interesting property of cast parts is that they can be made with internal cavities and odd-shaped internal structures that would be impossible to make any other way. Castings with large cross sections can be cored to reduce weight and prevent sink marks. Consider casting a

hollow ball. This could be done using a core, a mixture of sand and binder that hardens when cured, and one small core support hole that is filled in later. The core is usually hardened in an oven so that it can be handled. The shape is formed by using a mold called a core box. The core is designed to be inserted into the primary mold after the pattern is removed. The core is removed by breaking it into small pieces and pouring the pieces out through the support hole after the casting has been made and cooled. Using cores is not really as simple as I have outlined here. You should not attempt them until you are adept at making solid castings.

Figure 3 shows a simple pattern with only one parting line. Pattern dimensions must allow for the shrinkage that occurs as the part cools. Shrinkage coefficients

vary with the type of metal used and are specified in inches of shrinkage per inch of original dimensional length. Generally, published shrinkage coefficients for the various types of metal do not mention the temperature span over which the coefficient is valid. Pattern dimensions can be calculated very simply by multiplying the shrinkage coefficient by the final dimension and adding the result to the final dimension. Calculating the allowance for shrinkage is a rather crude process. Dimensional accuracies better than to 1/32 of an inch should not be expected. Tighter dimensions should be machined into the final casting.

The slope or draft on all surfaces perpendicular to the parting line is the taper that makes the pattern easy to remove from the sand mold. Draft angles can vary, but

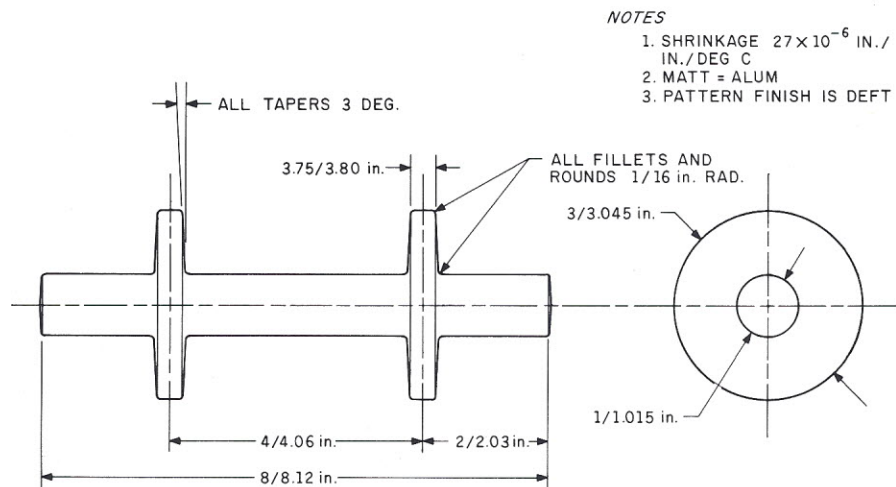


Figure 3. Example pattern with one parting line.

must always allow the parts to separate. Negative draft on a surface will hold the pattern in place, preventing it from being removed from the sand without disturbing the impression. An angle of three degrees works nicely. For deep parts, however, where the top of the mold must be lifted a long distance to clear the pattern, a steeper angle of one degree might be preferable to prevent a dimensional build-up that would be intolerable. Removing the pattern from the sand without disturbing the mold becomes more difficult as the slope becomes steeper. Choosing the optimum draft angle is a matter of experience.

Patterns like the ones shown in photo 4 can be made from solid blocks of wood, but it is usually easier to make them by gluing together several simpler pieces. Composite patterns of several different materials can also be made. When faced with the problem of building up large wooden sections for a pattern, the designer should consider standard thickness pieces. It is

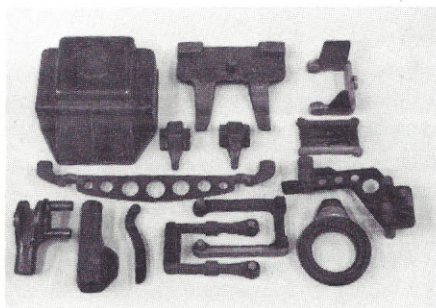


Photo 4. Avatar construction patterns.

cheaper to buy pieces of wood in standard sizes and glue them together than it is to buy one very thick piece of wood.

After the pattern pieces are glued together, all cracks and depressions should be filled with a good quality putty or wood filler. All sharp outside corners should be rounded, all inside corners should be filled and rounded, and the entire pattern should be sanded smooth. Once the glue and filler are dry, apply several coats of quick-drying lacquer. After each coat dries, use steel wool to smooth out the surface before applying the next coat. Finally, rub on powdered graphite until the surface feels slippery. The pattern is now ready to use.

MAKING A MOLD

Making good molds is a skill that is acquired only after a great deal of practice.

You must learn to gauge the wetness of the sand, to remove the pattern without disturbing the sand cavity, and possibly to do a little reconstructive surgery on a damaged cavity.

Making molds requires the use of cer-

tain tools, the most important of which is the mold box or flask. (See figure 4.) These containers, made of wood or metal, can be made in various shapes and sizes to accommodate different patterns. The box has only a few important functional features.

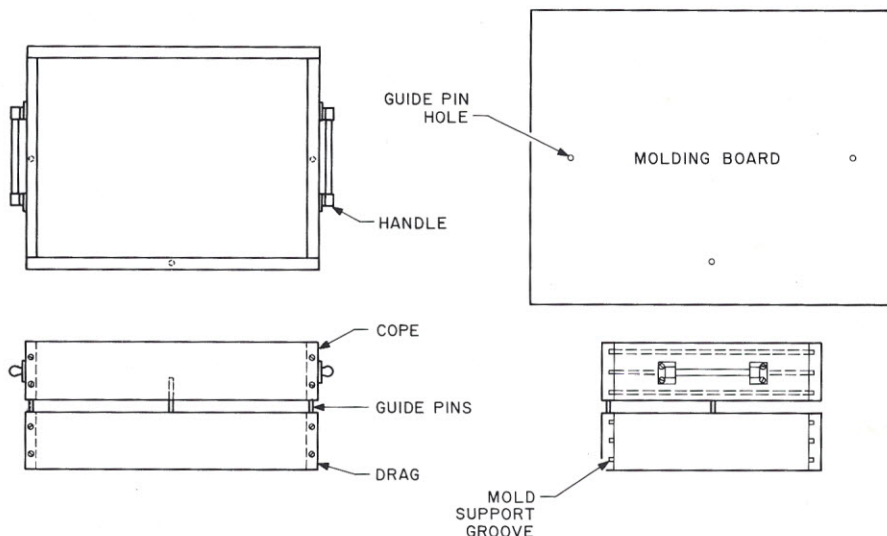


Figure 4. Simple two-part flask.

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If the part has only one parting line, the flask has only two parts. If the pattern has two parting lines, the flask will have at least three parts, and so on. A two-part flask has a top half called a *cope* and a bottom half called a *drag*. These two pieces fit together with the aid of guide pins that maintain alignment. The inside surfaces of the cope and drag are slotted. This provides a surface to which the packed sand will adhere. Handles on the cope, while not necessary, aid in lifting the cope off the drag.

The molding board serves two purposes. First, it provides a surface on which to lay the drag and the pattern when making the bottom half of the mold. Second, it serves as a base for the completed mold when transporting it to the foundry.

A number of other tools are useful:

- Rammers are used for packing the sand into the flask. They are usually made of hard wood with one large flat end, like a hammer, and a smaller wedge-shaped end.
- Brushes are used to clean the outside of the mold and patterns.
- A sieve is used to filter the molding sand and remove debris.

- Bellows, while not necessary, ease the removal of loose sand found in the mold cavity after the pattern is removed. A low-pressure air hose can also be used.

- A dust bag, usually made from porous cotton cloth, is filled with silica parting dust. The molder shakes the bag over the parting surfaces of the mold and deposits a layer of dust.

- A draw pin is an ice pick-like tool, sometimes having a threaded tip. It is used to remove the pattern from the mold.

- A sprue pin is placed in the cope when the sand is packed in. When it is removed, it leaves a hole through which the molten metal is poured into the mold cavity.

- A riser is sometimes used to provide a vent for the gases generated when the hot metal hits the moist molding sand. Risers can also be used to provide extra metal to reduce sink marks in castings with thick sections.

- Molding sand sticks together and holds a shape. Many different types of molding sand are available, each with distinct properties of coarseness, types of binders, porosity, etc. Let the foundry equipment supplier choose the type that best suits your needs.

MOLDING SEQUENCE

Making a mold begins by preparing the sand. The consistency of the sand should be such that you can squeeze a handful of it into a clump that will hold its shape when you let go. If the sand is too dry, it will fall apart. If the sand is too wet, too much steam will be generated when the metal is poured into the mold. This can cause blow holes in the casting and make the surface of the casting very rough and porous.

Once the sand is ready, follow this nine-step process to make a mold. The procedures are illustrated in figure 5.

STEP 1. Invert the drag and place it on the molding board. Lay the pattern inside

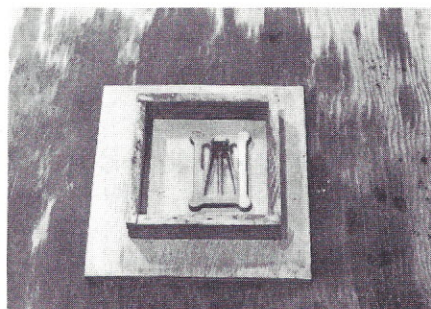


Photo 5. Pattern in place in drag.

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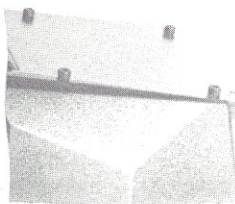
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the drag in such a way that it can be extracted from the top. Sprinkle parting dust over the pattern and on the molding board, using the dust bag.

STEP 2. Fill the drag with molding sand. Sprinkle only unclumped sand over the pattern using the sieve. Fill the remainder of the drag and carefully pack the sand tightly into every corner using the rammer. Overfill the drag with sand to ensure that it is completely filled.

STEP 3. Scrape off the excess sand using a wooden or metal straightedge.

STEP 4. Invert the drag so that the guide pins are up. Sprinkle parting dust over the pattern and sand.

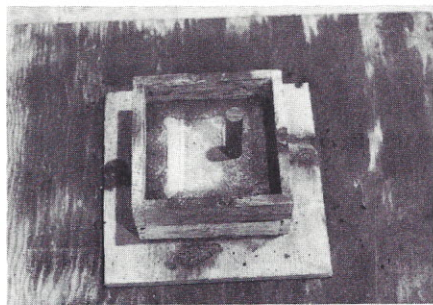


Photo 6. Sprue and cope in place.

STEP 5. Place the cope over the guide pins and set a sprue pin near where the metal should flow into the cavity. (See photo 6.)

STEP 6. Fill the cope with molding sand using the procedure outlined in step 2. Do not disturb the sprue pin while packing the sand around it.

STEP 7. After packing the sand very tightly, dig out a small pouring cup around the sprue pin. Wiggle the sprue pin free and pull it out. Using your finger, shape the pouring cup and hole to remove any sharp corners and loose sand.

STEP 8. Very carefully, lift the cope straight up off the drag. Be sure to lift it high enough to completely clear the drag before moving it sideways. Set the cope aside while you remove the pattern. Dig out a small channel to allow the metal to flow from the sprue to the edge of the pattern. Using the draw pin, remove the pattern by carefully lifting and tapping the pin until the pattern breaks free. (See photo 7.) Occasionally a piece of the cavity will break loose when removing the pattern. If it is a major piece, try to paste it carefully back in place with a little water. Remake

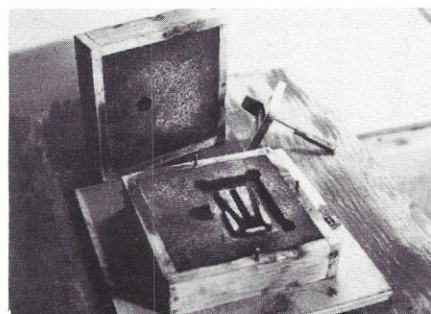


Photo 7. Pattern removed prior to closing mold.

the mold if patching does not work. Small pieces that break off will only cause flashing on the final casting that will have to be removed. Once the pattern is removed, use the bellows or air hose to blow out any loose sand.

STEP 9. Very carefully, replace the cope by realigning the guide pins and holes, and gently lower the cope back into place on top of the drag. The mold is now complete and ready to use.

MAKING A CASTING

Now that the mold is ready, you must prepare the metal. The metal to be melted

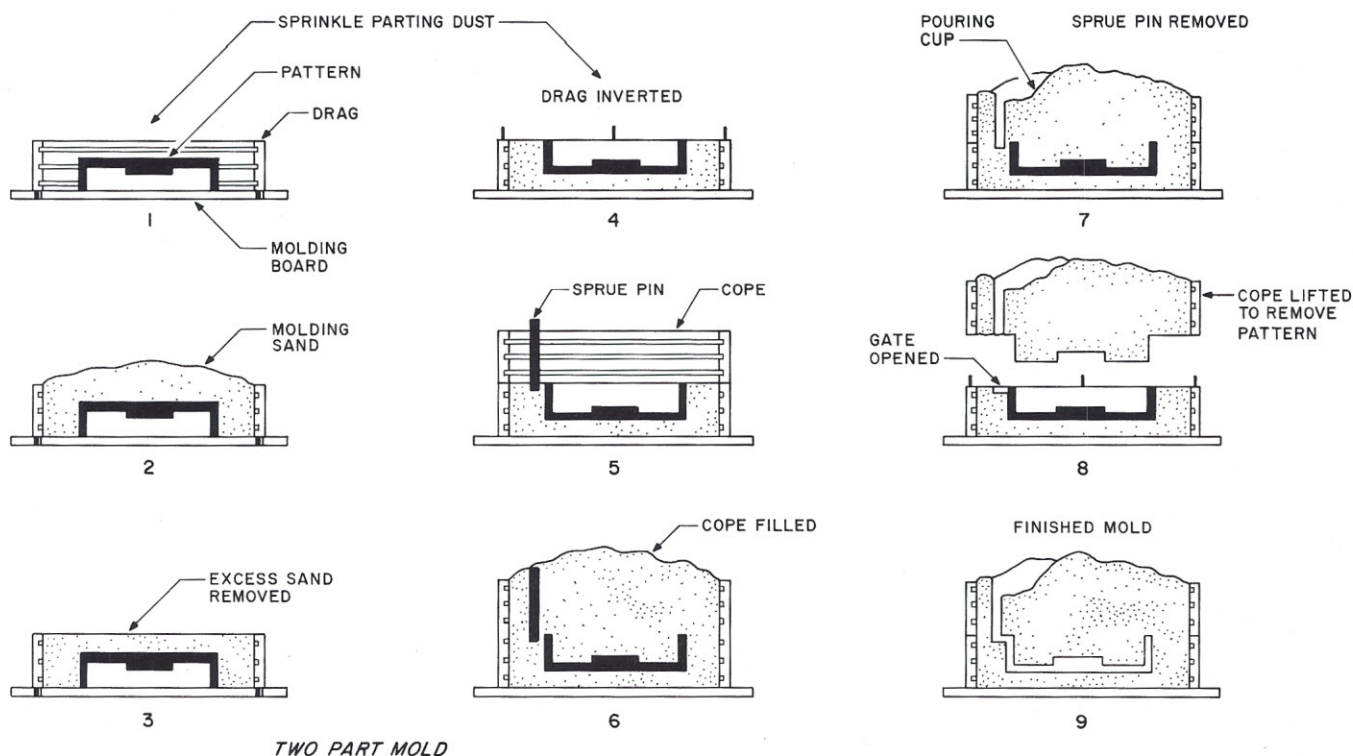


Figure 5. Molding sequence.

should be in chunks small enough to fit loosely in the crucible. If a piece fits too tightly, it may crack the crucible as it expands. Large chunks, as opposed to thin or flat pieces, will tend to produce less slag because they have less surface area to oxidize. Material should also be free of paint, oil, water, and other finishes which might generate explosive or toxic gases. When melting any metal, preheat it externally before adding it to the charge in the furnace. Preheating burns off or vaporizes any paint, oil, or water and reduces the possibility of an explosion due to trapped gases in the metal.

Since most of us cannot afford a thermometer capable of measuring the temperatures of molten metals, we must rely on a more qualitative technique. Listed in table 1 are the approximate melting temperatures of several common metals. Also listed are the temperatures and corresponding inside furnace colors.

The temperatures for the casting techniques described here are not critical. There are only two rules of thumb to consider: if the metal is not hot enough, it may solidify before completely filling the mold cavity; if the metal is too hot, the casting may end up with a very rough or porous surface.

Some of the necessary equipment is shown in photo 8. Obviously a set of

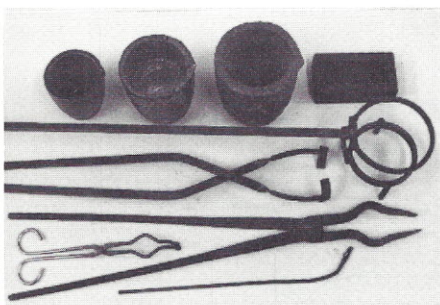


Photo 8. Crucibles, holder, and tongs.

crucibles is needed. I prefer graphite crucibles over clay because they last longer, and I can use them for melting iron. An ingot mold for the excess metal is handy. Several sets of tongs will be needed—one large pair to lift the crucible out of the furnace and another, smaller pair to add new metal to the crucible. Use the large tongs or a special pouring holder when pouring the metal into the mold. This special holder is very handy as it eliminates trying to manipulate a hot, heavy crucible while squeezing on the tongs. The last item

Color	Metal	Temp Deg. F
Normal	Lead	620
Dark red	Aluminum	1000
Cherry red		1300
Orange		1400
Yellow		1700
	Brass	1800
	Copper	1981
White		2100
	Gray Iron	2192

Table 1. Representative melting points and inside furnace colors.

needed is a piece of steel rod for removing the slag which forms on top of the molten metal. Skim the slag from the top of the metal before it is poured.

When you are ready to pour the hot metal, put on your gloves and face shield. Carefully lift the crucible from the furnace with the tongs and set it down. With a good grip on the crucible, quickly pour the metal into the sprue hole in a steady stream, never stopping until the sprue and pouring cup fill completely. (See photo 9.)

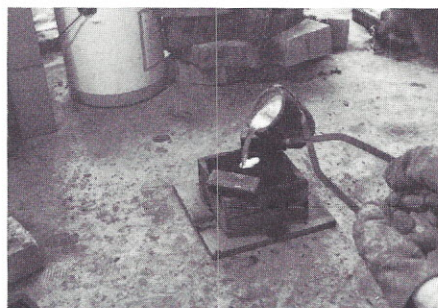


Photo 9. Pouring the metal into the finished mold. Note the weights on the cope.

The weights sitting on top of the cope keep it from floating up due to the internal pressure of the metal. After completing the last casting, pour the remaining metal into the ingot mold. Invert the crucible and set it aside to cool.

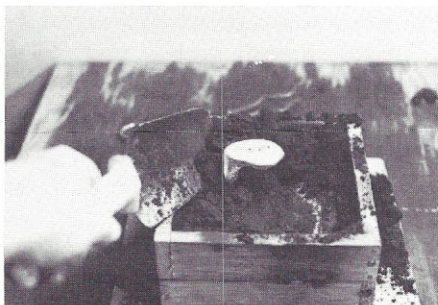


Photo 10. Removing the molding sand after casting has solidified.

After allowing several minutes for the metal to harden, remove the casting from the mold by digging it out of the sand as shown in photo 10. Remember to handle the casting with tongs since it may still be very hot. Do not quench the casting in water to cool it until it has air-cooled for a while. (See photo 11.) Clean and machine the casting only after it has cooled completely. Remove the sprue and any flashing that may be present. Apply a finish if necessary.



Photo 11. Final casting before sprue removed.

CONCLUSION

Making your own castings can add a new dimension to the construction of your robot. While it is conceptually a very simple process, requiring only crude equipment, it does take skill and judgement to design and make good quality castings. My advice, to those of you who want to try it, is to go to the library and find several books to read on casting techniques. If you decide to give it a try, remember—be cautious and always follow proper safety precautions.

Reader Feedback

To rate this article, circle the appropriate number on the Reader Service card.

72	82	92
Excellent	Good	Fair

Fantasy Meets Reality at

A refreshing approach to the concept of robotics is being set forth at the American Craft Museum II in New York City. A unique exhibition entitled "The Robot Exhibit: History, Fantasy, and Reality" traces the historical development of the robot from a creative, imaginative, and technological perspective. This exhibition represents the first attempt by a major American museum to present robots and robot images to the public.

The exhibit comprises more than 160 displays which include sculpture, prints, and drawings of robots. It provides the public with an opportunity to interact with a wide range of robots—toy, do-it-yourself, personal, and industrial— and automatons. In addition, sections of the show provide useful photographs, video clips, and slides which describe the development and applications of robots. Visitors can examine exhibits which explain some of mankind's earliest attempts to imitate life, such as

primitive automatons dating back to Hero of Alexandria (A.D. 100) as well as some of the most modern industrial robots.

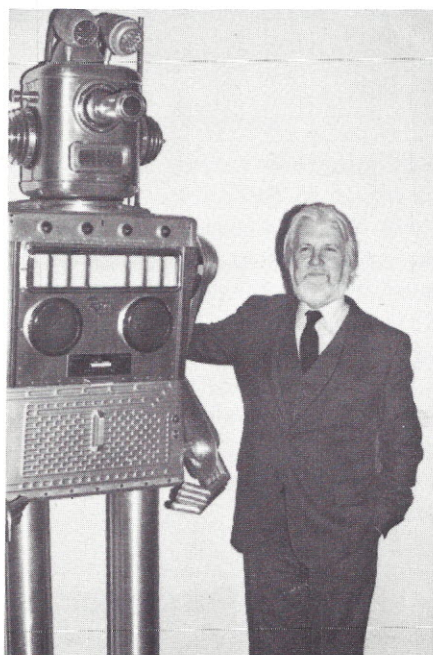
Robert Malone, guest-curator of the exhibition, says the exhibit is designed to "tap into a new kind of spirit of people's interest . . . and to deal with robotics in terms of fantasy and reality rather than just hard facts." This approach has helped create an effective format which exposes people in all walks of life to robots in an informative, amusing, and nonthreatening way.

The exhibit is designed to encourage visitors to browse around and to provide them with an opportunity to test out and play with the robots. "There is an enormous resistance to change because of the fear people have of the unknown," comments Malone. "We have tried to stress the approachability and user-friendliness of the robots by focusing on the fantasy and the artistic aspects of the exhibit. This helps break the ice."

Indeed, this approach has helped actively involve many of the exhibit's visitors with the robots on display. One robot named *TOT*, a robot manufactured by ComRo, Inc., greets people as they enter the exhibit. Children in particular are drawn to this diminutive robot. They crowd around *TOT* and talk with it. Using an interactive program written by its designer, Jerome Hamlin, *TOT* whirls around the museum floor, talking to visitors as it rolls by: "Welcome to the robot exhibit. Come in and see my friends. Pleased to meet you, nice to see you." Children show little fear of this electronic creation.

"I didn't realize the interactive potential of *TOT*," says Hamlin. "Children speak right back to the robot when it asks them for their names. The children aren't interested in the practical side of what it does, they relate to it as another person."

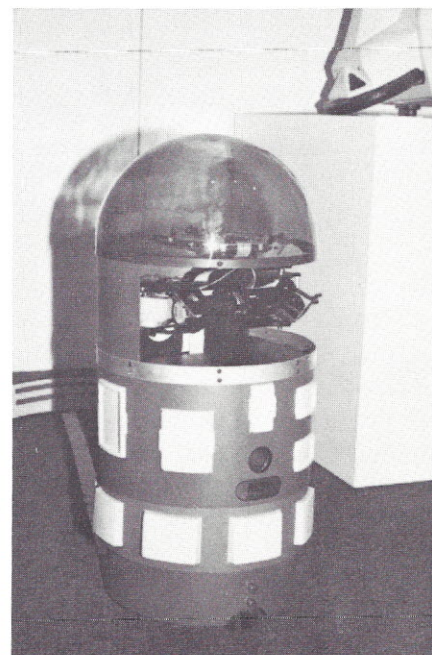
The Interpretive Robot section of the exhibit presents robots as they have been



Robert Malone, guest curator of the exhibition, poses with *Regal Robot*, a 1983 creation by Clayton Bailey.



Outline of Thomas Edison's 1894 manufacturing facility for the talking doll.



Commercially available robots, such as this RB5X, are also represented at the exhibition.

New York Robot Exhibit

depicted by authors, screenwriters, sculptors, and illustrators. It emphasizes the important role that fantasy and imagination play in the creation of real-life, practical devices.

"It's hard to clearly divide fantasy from reality," observes Malone. "Fantasy and imaginative thinking have led to reality. Reality is in turn being refantasized . . . This is a constant cycle. Things that were being discussed in the 1930s, 1940s, and 1950s

as science fiction fantasy are realities today." He cautions, "Robots are disconnected from people. You have to talk to people and educate them in order for change to take place. We are not going to have a robot revolution in the factory unless we deal with people's suspicions. Otherwise, they will downgrade robots."

"I saw this robot in the movies," comments a young man playing with a toy version of the Star Wars hero R2D2. "Hello

there, how are you?" inquires a young girl of Androbot's *Topo* robot. It is clear that people of all ages leave the exhibit with much more positive feelings about robots than when they entered. The exhibit plays a major role in demystifying this new area of technology, by showing a clear connection between our imagination and our desire to create.

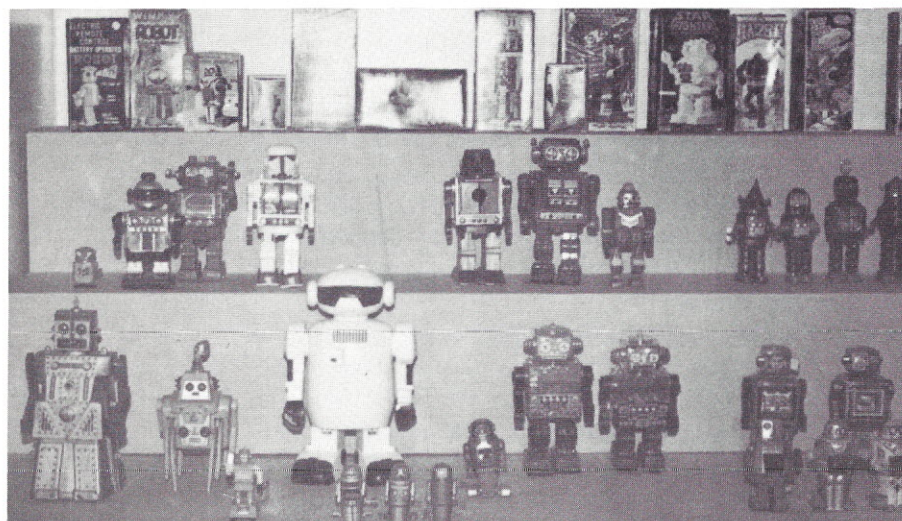
As this issue of *Robotics Age* goes to press, the show is about to start a 2½-year national tour. For information about schedules, contact: Sherry DeLeon, Coordinator of Circulating Exhibits, American Craft Museum II At International Paper Plaza, 45 West 45th St., New York, NY 10036.

All photographs were taken by Eileen Power during a visit to the American Craft Museum at International Paper Plaza in New York City.

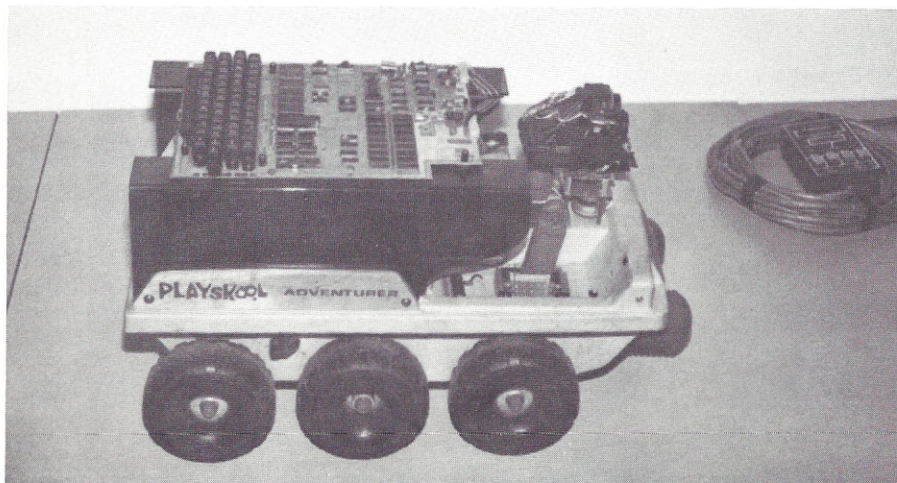
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Excellent	Good	Fair



Robot toys have been with us for years. Seen here is a selection ranging from simple mechanical windup toys to modern electronic robot toys.



Gene Oldfield of Robot Repair created this mechanized *Playskool Adventurer* for wandering about the house.



Light industrial robots, such as this Seiko Instruments USA, Inc., *Seiko RT 3000*, demonstrate their precision and agility.

Meccano and the Home-Built Robot

Keith W. Cameron, M.D.
1368 Piper Road
Spring Hill, FL 33526

Would you like to build your own robot from a large selection of ready-machined parts? New wrist or elbow ideas require belts, cables, sprocket chain, metal strips, and small motors. The parts must be interchangeable and easily dismantled in order to allow design modifications.

Welcome, then, to Meccano, a metal construction system that is an available source of the mechanical parts mentioned above and many more. Although not well-known in the United States, Meccano has been very popular in Europe, Canada, and many other parts of the world. It has been the childhood tool of many creative young minds, enabling them to give substance to their imaginings. Meccano systems have been widely used in industry for their adaptability to experimental projects; they are well-suited to all forms of experimental model-building.

The accompanying photographs show some of the available Meccano parts and also show a fully operational model of the Rhino XR-1, with Linear Slide Base and remote control, built entirely of Meccano parts. This model drew much attention as it performed flawlessly throughout the three days of the *Toronto Hobby 82* show in the International Center.

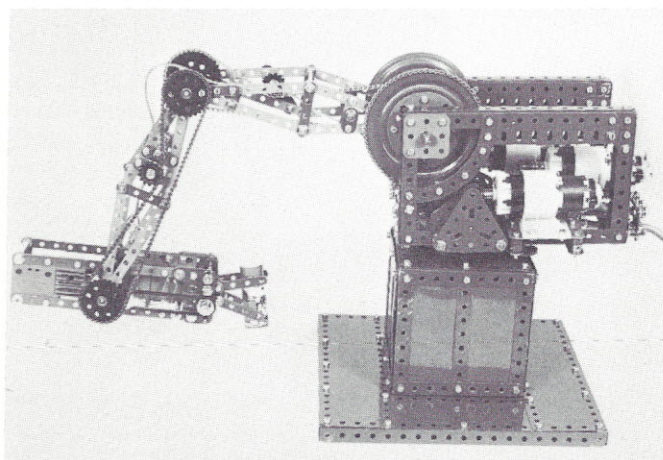


Photo 1. A general view of the completed model.

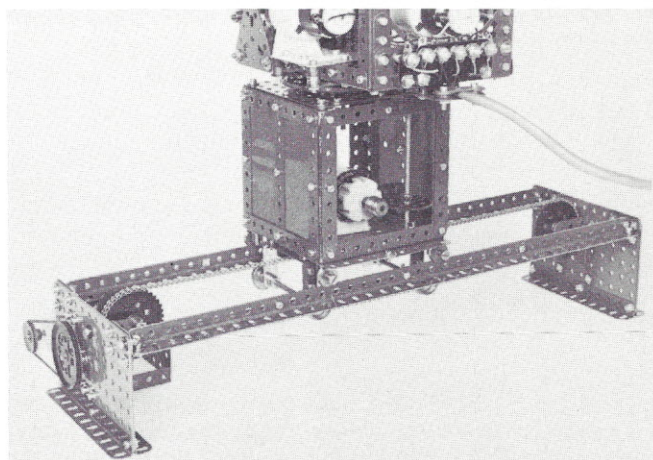


Photo 2. The Linear Slide Base of the Rhino model. A motor-gearbox combination drives a shaft through a band and pulleys. This shaft carries a worm drive to a second shaft with a sprocket wheel around which a chain passes to another sprocket wheel at the far end of the base.

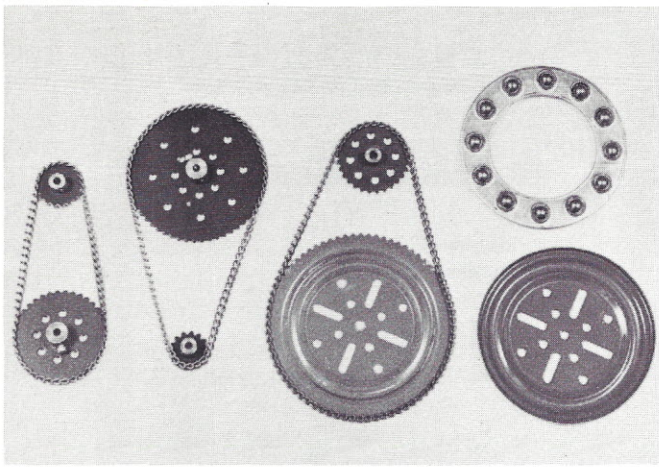


Photo 3. The range of sprocket wheels in the Meccano system, namely $\frac{3}{4}$ in., 1 in., $1\frac{1}{2}$ in., 2 in., 3 in., and 4 in. diameter. The largest sprocket wheel has a flange for use with a ball cage. The smooth-edged race is also shown; this part is used in the model Rhino to provide a low-friction rotational bearing for the main mechanism housing.

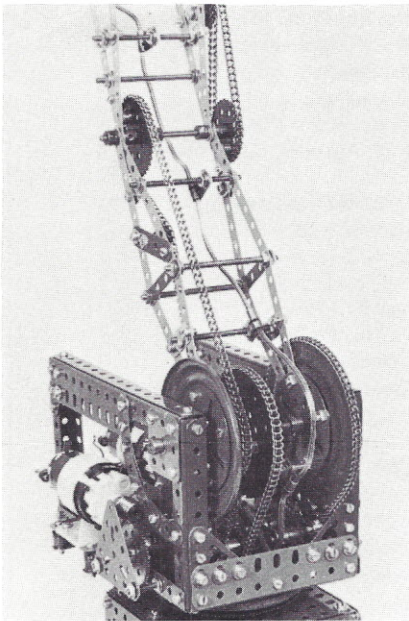


Photo 4. The sprocket chain system is used to control movement of the shoulder, elbow, and wrist joints of the robot. The smaller sprocket wheels provide the input drive to give good mechanical advantage. They are also used as idler wheels, and these are mounted on slotted-hole strips to allow adjustment as the chain slackens through use. This photo also shows one of three motor-gearbox combinations mounted on the rotating base. A worm gear on the output shaft drives a 60-tooth gear keyed on a shaft also carrying (inside the frame) a pinion which meshes with a further 60-tooth gear on the rod driving the small sprocket wheel.

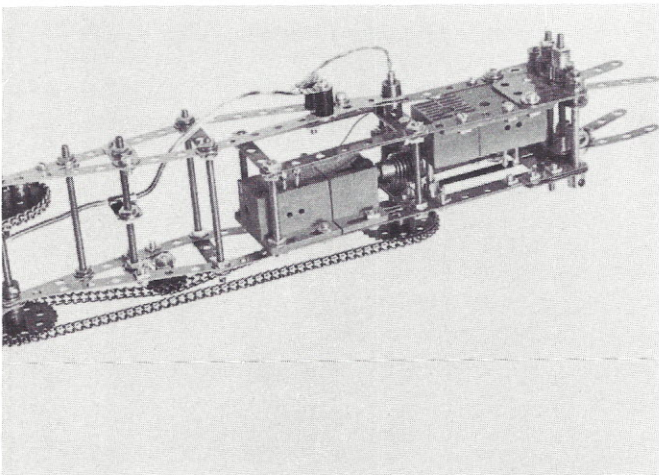


Photo 5. The hand and its two miniature motor-gearboxes, one working the wrist joint through a worm drive, the other gearbox moving the fingers to which it is linked by a driving band and pair of threaded rods. Note that the wiring to the motors passes along a keyway in a halfshaft at the wrist joint.

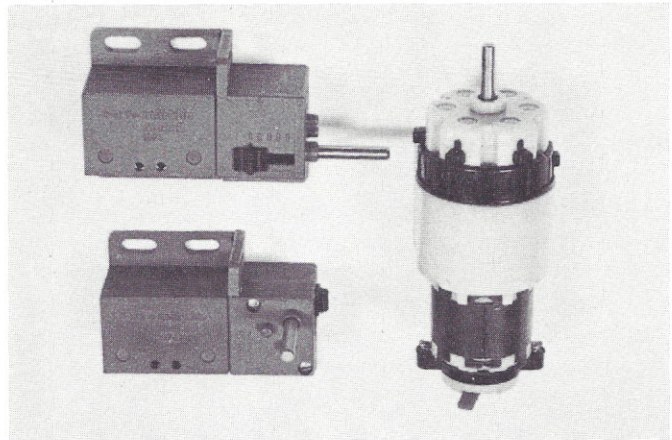


Photo 6. Two types of motors, the larger one providing a choice of six different output ratios, the smaller providing a choice of five different ratios—note the black knob and the five lines. These motors are DC permanent-magnet types that can be remotely reversed. They provide fully adequate power with 9 V input. Most internal gears are plastic, but with reasonable care, provide long life service.

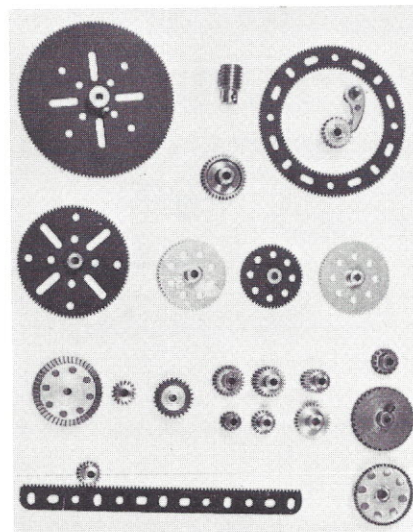


Photo 7. Some of the many types of Meccano gears. Note the wide range, from small $\frac{7}{16}$ in. pinion with 15 teeth to a large gear, $3\frac{1}{2}$ in. diameter with 133 teeth. Numbers of teeth are carefully chosen to provide exact reduction ratios. Note also the bevel gears, the pawl and ratchet, the crown wheel, and the two sizes of helical gears. There is also a rack strip.

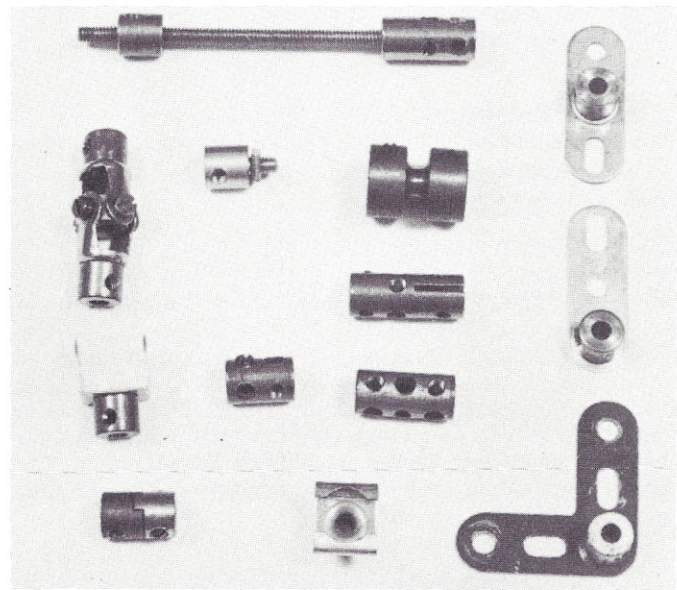


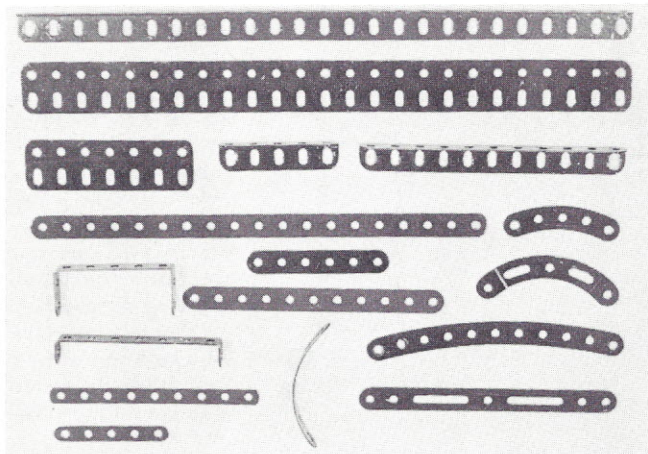
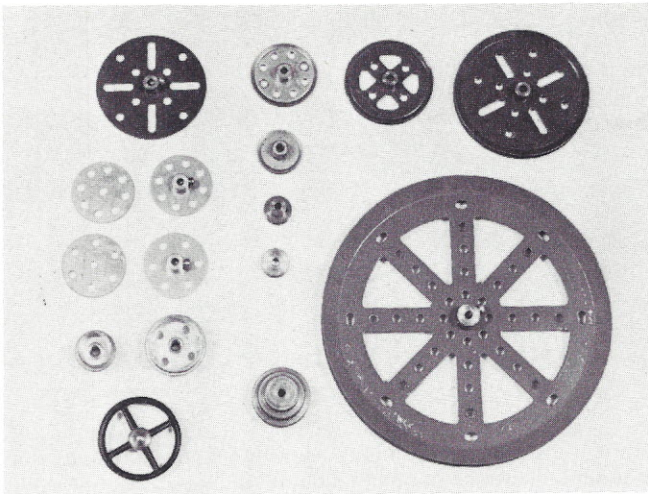
Photo 8. A few of the great number of small special parts available. Here are seen several kinds of cranks, couplings, dog clutches, a universal coupling, a socket coupling, and fittings for threaded rods.

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Worldwide interest in Meccano model-building at an adult level of considerable sophistication has increased the number and size of clubs and guilds in many countries. Details of these clubs can be obtained by anyone whose appetite for Meccano-built designs has been whetted, by writing to any of the above sources. The author would also be happy to correspond with anyone interested in the subject.

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The Role of Robots in Flexible Manufacturing Systems

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Rochester, NY 14623

Factory automation has been actively pursued in the industrialized nations of the world. One of the most promising concepts employed to that end is the Flexible Manufacturing System (FMS). Many large manufacturing organizations expect FMS to help solve their productivity problems and improve their business performance. They see the FMS as a business-driven route for improving profitability by reducing lead times, allowing rapid response to market conditions, increasing flexibility to accommodate a variety of product lines, and reducing manning levels. The FMS installations designed over the last few years have increasingly used robots as part of the system to achieve that competitive edge. This article describes the basic concepts of Flexible Manufacturing Systems and illustrates, with examples, the role of robots in FMS.

FLEXIBLE AUTOMATION

Until the 1950's, the automation of manufacturing processes was limited to mass production systems. These systems are often referred to as "transfer line

systems" to indicate the manner in which the parts are transported between work stations. Transfer line systems are designed to be used for a single type of product having a high volume of production. They are also highly efficient and are known for their extensive utilization of machines. Production in small quantities is uneconomical with these systems.

Also, since the 1950s, the metal manufacturing industry, which accounts for more than 30 percent of the GNP in most of the industrialized countries, has demanded more diversified products in smaller quantities. The invention of computer numerically controlled (CNC) tools responded to these changing needs. These machines can provide middle-to-low-volume production capacity and high flexibility, making them suitable for small batch manufacturing. However, these systems have some drawbacks of their own, such as longer setup times, large work-in-process inventory, low machine utilization, and high manning levels. Flexible Manufacturing Systems evolved in the 1960s from the idea of combining the best features of the transfer line systems with those of the CNC machines.

FLEXIBLE MANUFACTURING SYSTEM DEFINITION

As yet, there is no precise and universally accepted definition for FMS. However, an FMS can be described as a process facility under total computer control, with an automated work flow system producing a variety of parts in small batches within the stated capability and within a predetermined schedule. In simple terms, it can be defined as a system providing mass production economies in a batch production environment.

At the center of the FMS concept lies Group Technology. Group Technology is a management philosophy which, when applied properly, logically groups parts into part families. A flexible manufacturing system utilizes this philosophy and accordingly determines a single family of parts to be processed. The system employs one or more machining centers designed to process, at random, any number of parts belonging to the predetermined part family. The basic mechanism utilizes the similarities of parts in a part family and reduces the setup and process times. The end result is increased production efficiency.

FLEXIBLE MANUFACTURING SYSTEM INSTALLATION

Figure 1 shows the components and layout of a typical FMS installation. The components include: Machining Centers, Wire-Guided Robotruck System for part transfer; Part Washing Station, Tool Load/Unload Station, Tool Magazine, Pallet/Part Magazine, Pallet/Part Load/Unload Station, Computer Control, and Scrap Removal System.

FLEXIBLE MANUFACTURING SYSTEM OPERATION

The principles involved in Flexible Manufacturing Systems are shown in figure 2. First, a program is loaded into the computer. When the program is run, it schedules, monitors, and controls the machining operations for a specified number of parts. During this period, the work pieces are mounted onto pallets, balanced, and clamped. The pallets, loaded on a robotruck, carry the work to the various machining centers. The machining operations take place in one or more of the machining centers, depending upon the system complexity and production volumes.

The computer continuously monitors the components under its control and makes necessary decisions concerning the various functional aspects of the system. The computer identifies the needs of the FMS components and allocates resources in the form of machining cells, tools, fixtures, material handling systems, and inspection modules. The only human interference in the machining process occurs when there is a breakdown in the system function. If a breakdown occurs, the system diagnoses the problem and sends a message to the maintenance personnel.

ROBOTS AND FMS

A robot can change its movements freely according to the instructions given to it. It has the flexibility to perform a variety of tasks within its working environment and according to a predetermined schedule. These characteristics qualify robots as ideal Flexible Manufacturing Systems components. Robots may perform a variety of functions in an FMS operation. These functions include: loading and unloading of work pieces and tools, machining, assembly, finishing, painting, and inspection.

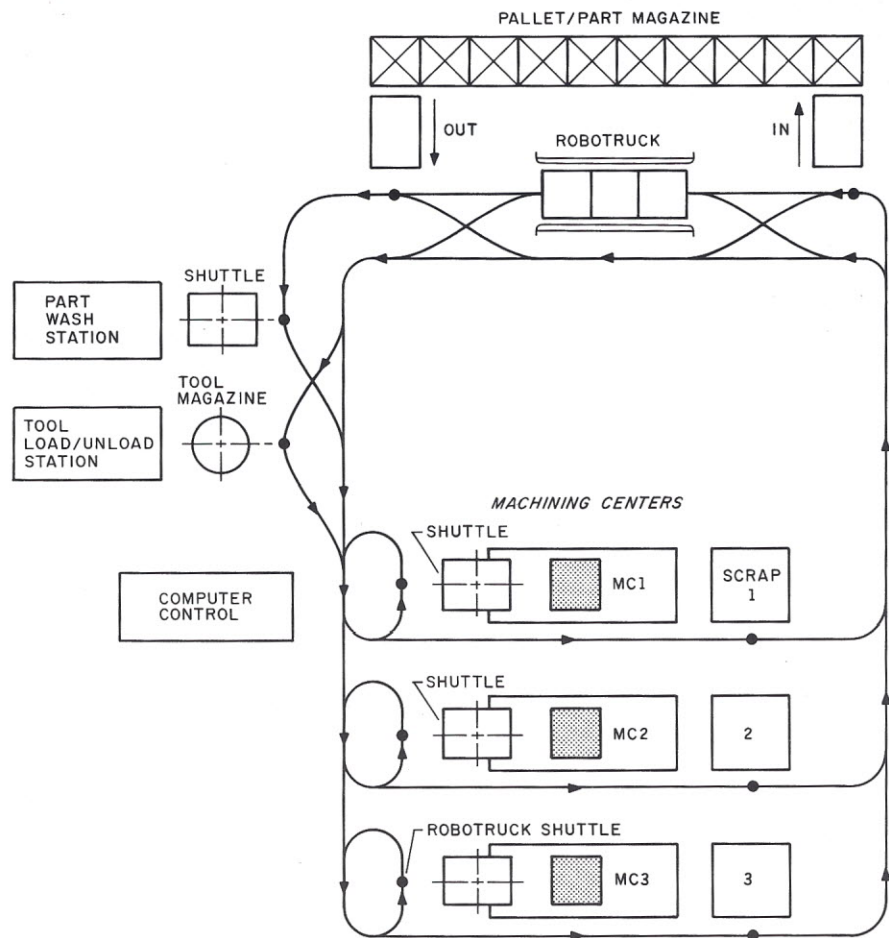


Figure 1. A typical FMS installation consists of machining centers, robotruck transport system, part washing station, tool load/unload station, tool magazine, pallet/part magazine, pallet/part load/unload station, computer control, and scrap removal system.

The robots may function as part of a machining cell or as machining cells themselves. Special types of robots, known as robotrucks, are used exclusively in flexible manufacturing systems for transporting work pieces. They are either wire-guided or rail-guided vehicles operating under computer control. These transporting mechanisms, with their increased flexibility and reduced capital outlay, appear to be the most popular means of transporting material between machining centers.

Although robots are used in flexible manufacturing systems in various ways, this article describes only those applications involving painting, assembly, and load/unload operations.

Painting. A typical FMS installation built for a painting operation is shown in figure 3. This system consists of a load/unload station, a preparation station, a painting station which uses two robots, a transport mechanism for part transportation, an oven to cure the paint, and a computer to

control the functions of the FMS components. The computer controls each of the elements with the help of separate control units. All the control units are synchronized to the conveyor speed.

System operation is very simple. The robots are first taught how to paint the appropriate portions of the part. The parts are then loaded onto the conveyor at the loading station, degreased at the preparation station, and moved to the first painting station. Photoelectric sensors monitor part movement. When a part arrives at the first painting station, Robot 1 paints half of the part. The part then moves to the second station, where Robot 2 paints the second half of the part. From there, the part moves to the oven for curing and finally to the unloading station.

Functioning as central units, the robots in this installation are an integral part of the flexible manufacturing system. The system paints in batch quantities of less than 1000 and responds quickly to

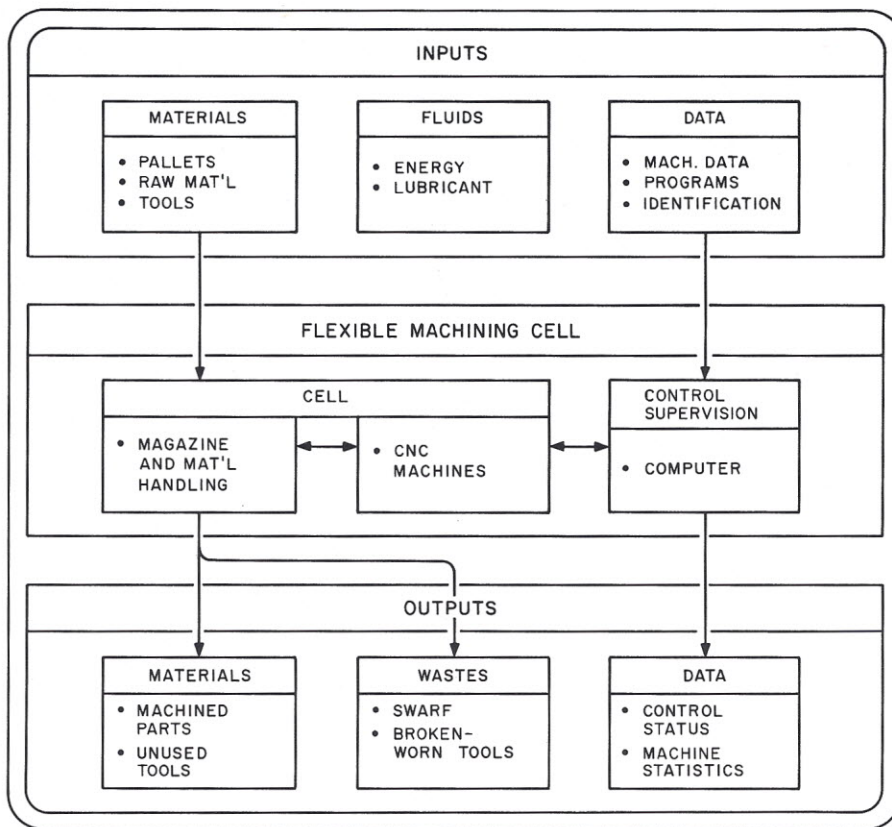


Figure 2. Inputs such as raw materials, energy, and machining data flow into the machining cell which operates under computer control. Outputs such as finished machined parts, scrap material, and control data are produced.

changes in customer demand. As a result, productivity is increased.

Assembly. An assembly operation consists of several steps. Parts are brought to the assembly station, where they are posi-

tioned and fixed. The parts are then assembled and inspected. Finished parts are removed in preparation for final assembly. Assembly may involve screwing, press fitting, fitting, bonding, caulking, etc.,

of the parts supplied to the assembly station.

The nuts and screws used in the assembly are usually supplied by simple, mechanically operated units, such as vibratory ball feeders. The main parts to be assembled are transported to the assembly station by means of conveyors.

Flexible manufacturing systems using robots for assembly vary from one to another in their configuration, depending on the characteristics of the parts to be manufactured. However, the assembly cell usually consists of the assembly robots, specially designed grippers to perform such operations as caulking, assembly machine components such as spiral screw machines, presses, and various sensing devices. The sensing devices may vary in complexity from tactile sensors to vision sensors.

One popular FMS configuration that uses robots for industrial assembly applications is shown in figure 4. The figure shows the part, which was loaded onto a pallet and then brought to the assembly station on a mobile conveyor, in position for assembly. Hydraulically activated pins hold the pallet in position. The robots used in these applications pick the components from the part feeders and perform the assembly operations. Once the operation is completed, the holding pins are deactivated and the pallet is allowed to move to the next work station.

An assembly cell such as this is expected to be highly flexible, capable of assembling

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a variety of products, efficient under frequent setup changes, easy to set up, and able to function unattended.

Loading and Unloading. The most general case of a machining cell using a robot for loading and unloading is illustrated in figure 5. In this case, the work is brought to the machining cell by a conveyor. The control system activates the robot arm, which picks up the suitable gripper from the hand-supply storage. The robot then moves to the work, grips it, transports it to the CNC machine, and orients and positions it on the work table. Once the machining is completed, the robot removes the part and places it at the output station for further processing. The system monitor detects any abnormalities and reacts accordingly. The robot performs the sequence of operations just outlined for a given batch of parts before it changes the gripper for another batch. The variety of the parts that can be machined in this cell is determined not by the robot, but by the CNC machine.

CONCLUSION

Increasing customer demand for diversified products has pushed the manufacturing industry toward batch production environments, making the Flexible Manufacturing System concept very appealing. The success of FMS depends heavily upon the flexibility and reliability of its components. With their excellent characteristics and adaptability, robots are gaining importance as FMS components. Their role will be further enhanced as they gain more sensing capabilities.

REFERENCE

Purdom, Peter B. and Tony Palazzo. "The Citroen Flexible Manufacturing Cell." *First International Conference on FMS*, Brighton, U.K., October 1982.

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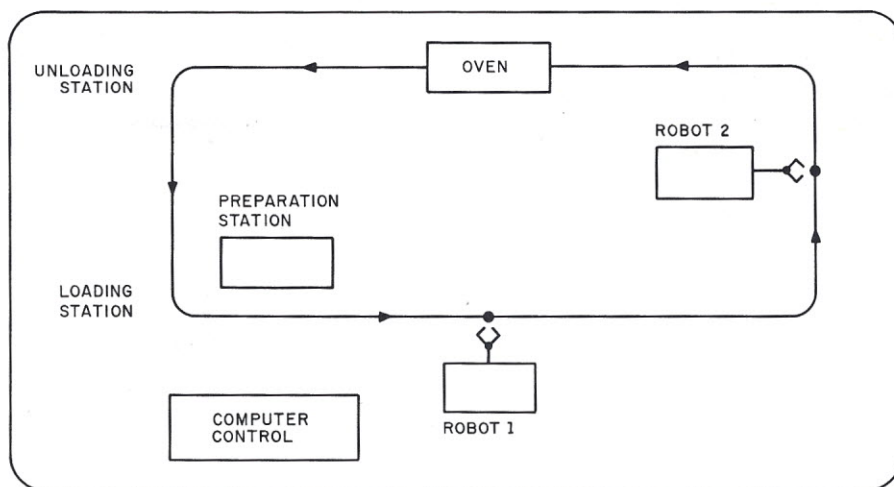


Figure 3. A typical FMS painting operation consisting of two painting robots, a curing oven, and preparation area.

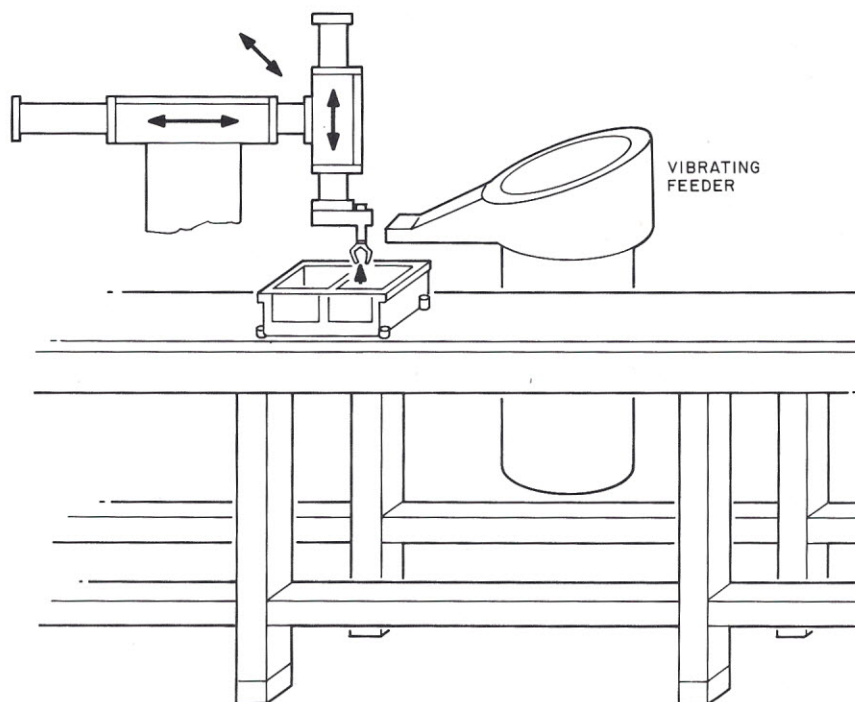


Figure 4. The assembly robot picks the part from the feeder and performs the assembly operations. The holding pins on the pallet are deactivated after the procedures are completed.

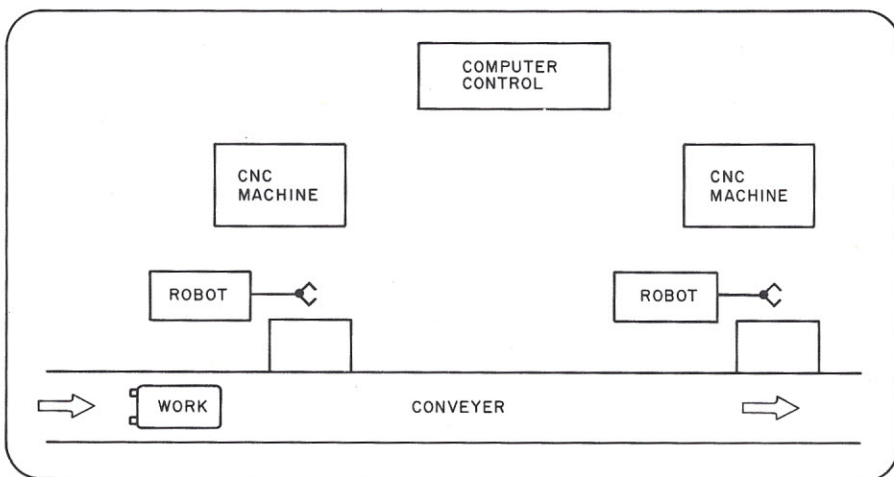


Figure 5. The robot moves to the work on the conveyor, grips the piece, transports it to the CNC machine, and positions it on the work table. The part is removed after machining and sent on for further processing.

A Review of the Colne Armdroid I

Derek F. Stubbs
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Vicksburg, MI 49097

The Armdroid I, made by a British company called Colne Robotics, is available from the U.S. distributor, D&M Computing, Inc., Box 2102, Fargo, ND 58107. The company founder is John Reekie, who is sometimes referred to as "the Henry Ford of robotics" because of his dedication to low costs and his prolific product line. The Armdroid II is a \$4000 industrial robot, while the Zeaker is a mobile, turtle-type robot selling for less than \$200. A video-

guided mechanical arm is soon to be available.

The Armdroid I is a programmable robot arm which can be driven by inexpensive, readily available microcomputers. I controlled mine with a Timex/Sinclair 1000™. Although the T/S 1000 is no longer being manufactured, they are easily found at computer meetings and yard sales. You can buy boards to control the arm with other computers, such as the Apple II™.

The arm can be purchased either assembled or in kit form. Available accessories include a 110 VAC to 13.8 V transformer, an RS-232 interface, a cassette program, two manuals, and all necessary cables. I opted for the ready-assembled version. It plugged together with no problem (I found no instructions, but it was quite obvious). The cassette loaded in a few minutes, and I was ready to learn how to manipulate and program the arm. Frankly, I was surprised

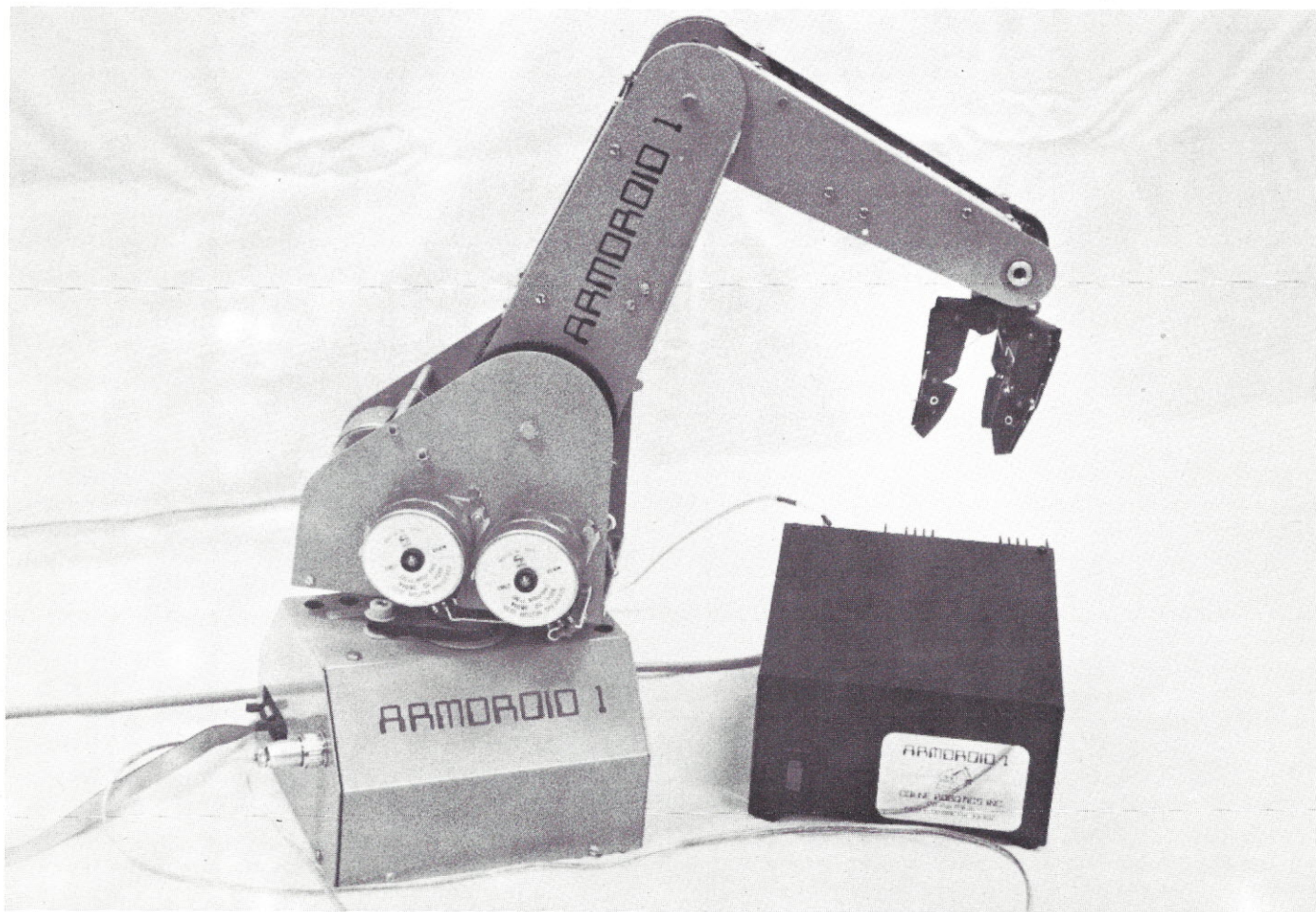


Photo 1. Overview of the Colne Armdroid I

at how easy it all was. Then I stepped back to ask myself, "Now what can I really do with this, and what is it?"

THE ARM

The arm has a shoulder, an elbow, a wrist, and a gripper. These joints are driven by six motors which activate a rubber belt-driven gear array. The gear array, in turn, manipulates the joints using string cords. The shoulder rotates 360 degrees in the horizontal plane upon a sturdy base. You are unlikely to tip the base over before you overload the gears and motors; however, the base should be anchored for safety. When a joint reaches its limit, or the pickup weight is too great, the cord drives start to slip. This reduces the chance of damaging the arm.

The shoulder can rotate the upper arm from 45 degrees below the horizontal to 45 degrees beyond vertical—a range of 180

degrees. The shoulder-axis-to-elbow-axis distance is 19.5 cm. The forearm rotates in the same vertical plane as the shoulder in the arc-range 135 degrees to 225 degrees. Thus it mimics the human forearm in flexion on the upper arm, but is more flexible, by 135 degrees, in extension. The elbow-axis-to-wrist-axis distance is 16 cm. The wrist axis is 10 cm. from the gripper tip. The wrist can be rotated 360 degrees about the long axis of the forearm. It can also be flexed 135 degrees onto the forearm or extended 90 degrees—both movements being in the same plane as the shoulder and elbow.

Thus the Armdroid I can reach an outer envelope, which is a hemisphere of radius 46.5 cm. with the center pivot as its center, and a circle on the table top with a radius of 45 cm. (The base of the shoulder rotation plane is 12 cm. above the table top). The gripper tips can touch anywhere within this region, except the central volume occupied by the base.

The gripper has a very interesting de-

sign. There are three fingers, each with a proximal phalanx of 3.5 cm. upon which a distal phalanx of 3 cm. flexes and extends. The gripper will close entirely or open to grip an object up to 10 cm. in diameter. It picks up a full wine glass, 7 cm. in diameter, with no problem. Each finger is fitted with a rubber pad to aid in gripping slippery and fragile objects. The gripper can easily hold an egg—although it is strong enough to break it. (I do not recommend testing this second benchmark—it gets to be messy.) A pencil can also easily be held.

The cords which drive the arms are all attached with springs. This ensures that a suitable tension is maintained, and no *relaxation* occurs as the arm operates.

The motors run a little hot, and I smelled burning paint for the first few hours. A call to Colne Robotics assured me not to worry about this. You can turn the motors off from the keyboard, or simply switch off the transformer during rest periods.

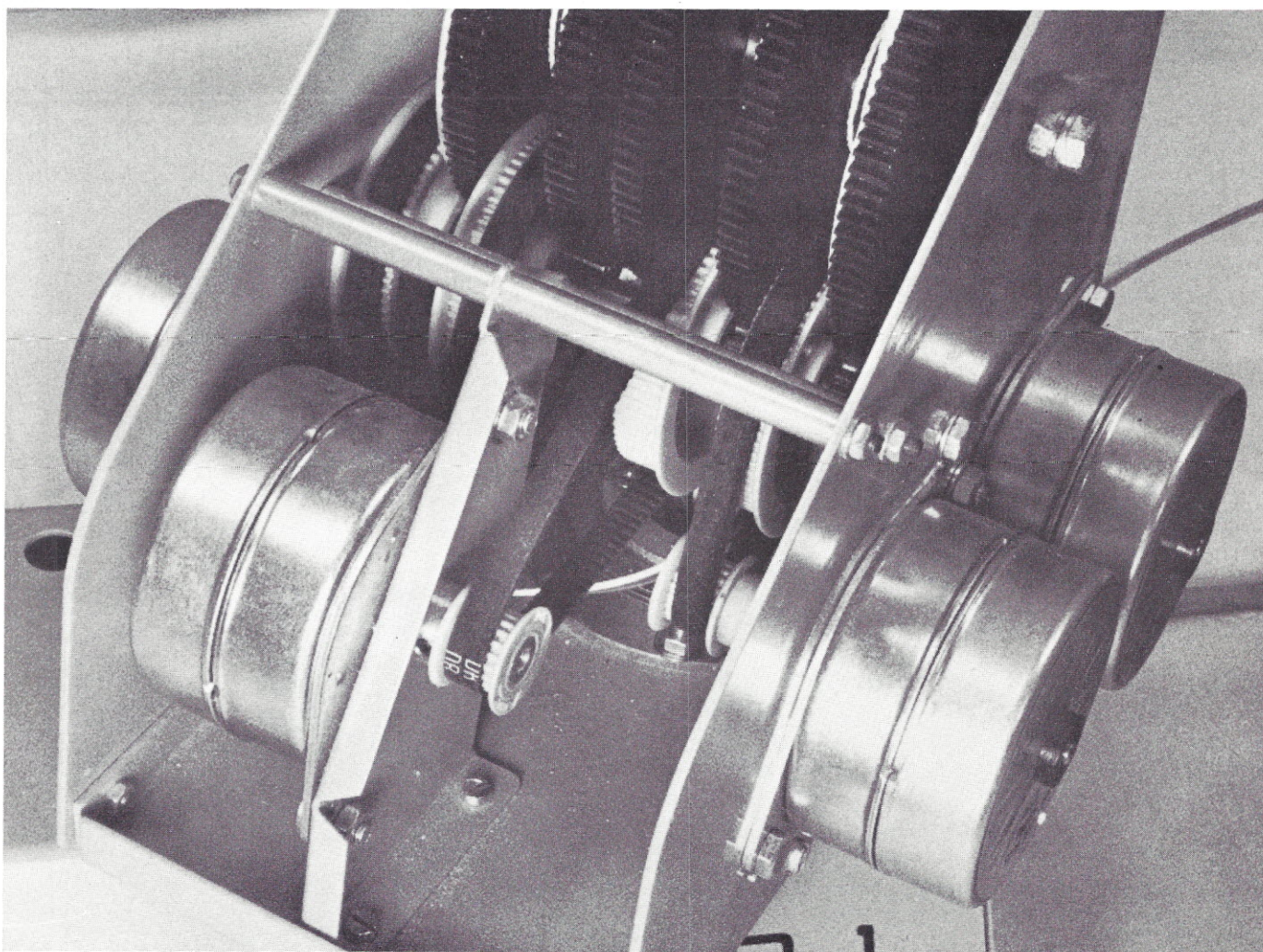


Photo 2. Rubber Belt-Driven Gear Array

DOCUMENTATION

The 78-page main manual is a well-produced and clear document on construction and operation. There are many fold-in diagrams to help in building the device. As I said, I did not construct my Armdroid, so I do not know how good those instructions are. I read them and they seemed clear enough. Some special hex wrenches are supplied for adjustments, but I have never needed to use them. The manual contains source code routines for operating the Armdroid.

The second manual is 39 pages long and describes how to use the Armdroid with the Timex/Sinclair 1000. A complete listing and explanation of the driver program is given. I found this very useful and well written. However, with regard to applications, you are on your own; I would have liked some examples. I understand an upgraded manual is to be released shortly.

OPERATING ARMDROID

After loading the cassette tape, I immediately saved the program on my Aerco disc, so that I could load it in seconds in the future. The Armdroid interface did not interfere with the areas in memory that are used by my Aerco disc system or my Memopak Centronics™ interface, so I was able to list the program, write, and copy programs while the robot interface was connected. I was also able to copy menus in the program for use as reference cards.

You can operate the robot remotely from the Timex/Sinclair 1000 keyboard. Pressing any one of 16 keys activates one of the joints and sends it through its range of motions. I recommend you play at this activity for some hours, so that you can get a feel for the individual movements necessary to accomplish an overall movement. Learning to pick up an object and put it down in another place may require several

hours. Still, it took you over a year to learn how to do this with your own arm. To accomplish a particular movement, a series of motions must be activated, each for a certain length of time.

Your second project should be to read carefully through the entire manual. I was equally impressed and daunted by the complexity of the software. Many useful subroutines have been provided, so you do not have to reinvent the wheel. You can execute motions with the Armdroid, and the program will remember the kind and speed of the motion.

The Armdroid software makes it easy to perform a movement sequence. You first reset the program and drive the robot to the point where you want to start the sequence. You then drive the arm to points two, three, and so on, and press *P* to save each point location. Then, going back to the menu, you have a number of choices. The program has stored the points and can

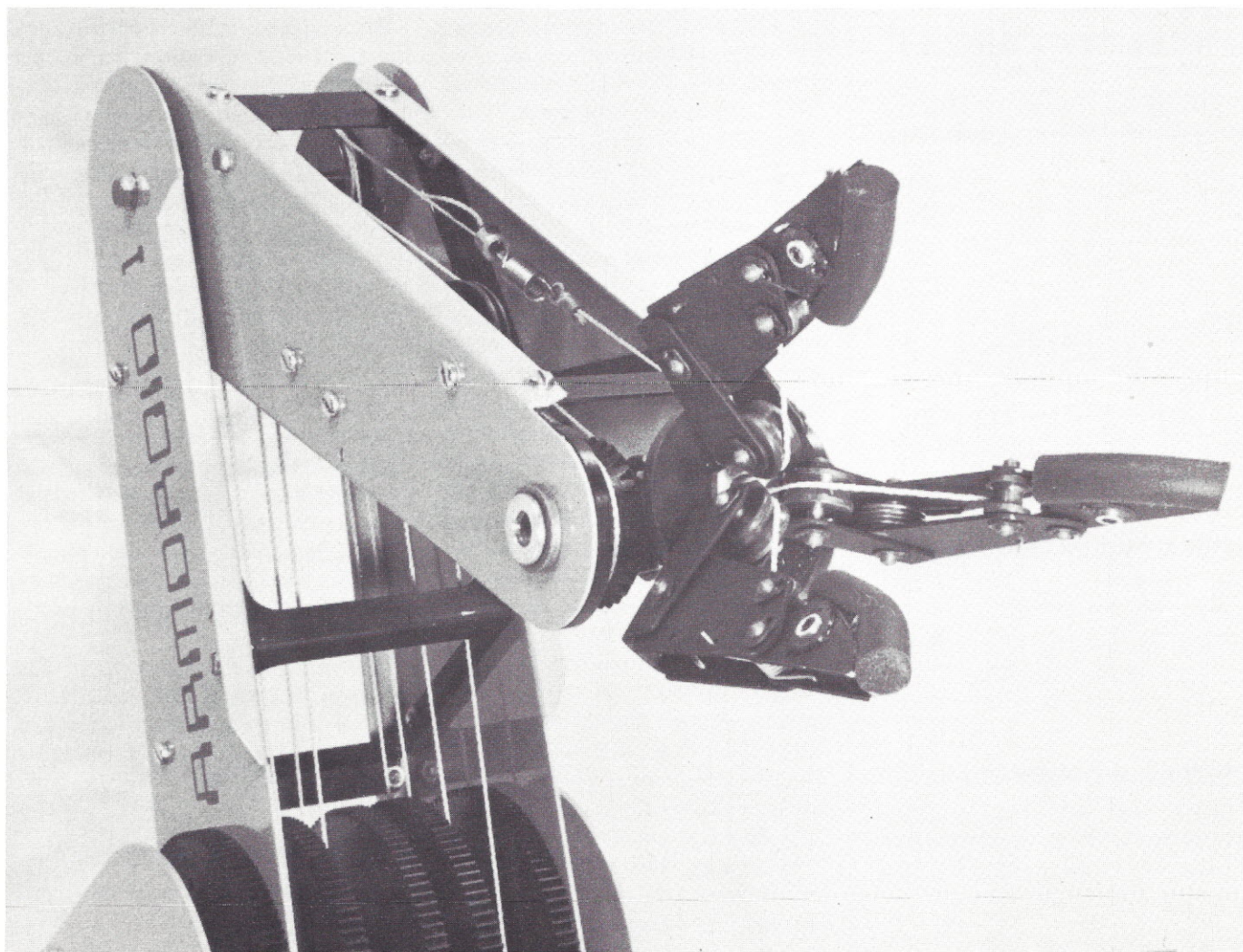
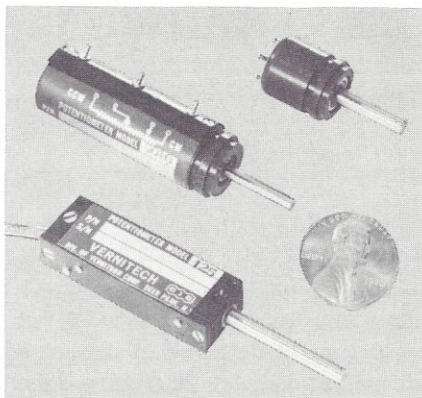


Photo 3. Gripper Showing Three Finger Arrangement



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get to each one from the previous one in the most economical way. You can *home* the arm; get it to go through your sequence of points, once or as many times as you wish; and you can even alter the sequence of points. All of these actions are accomplished by simply touching an appropriate key. There is no need to use the enter key or any multicharacter commands. From the user's point of view, learning and operational ease and the menu-driven features make this machine an excellent teaching tool. Three children, aged six to ten, learned how to operate it in a few minutes. "User friendly" is a very overused phrase, but it certainly is appropriate in the case of the Armdroid I.

I tried out the Armdroid with two practical movement sequences. Both took only a few minutes to program. In the first movement I had the arm pick up a ping-pong ball and drop it in a box in another position. The movement usually succeeds, but not always. Moving any of the arm joints causes some small motion in another joint. Thus, you need patience, practice, and minor adjustments for such movements to work. The finer the movement, the more difficult it is to repeat.

One solution to the problem is to move rapidly to the general area where the object to be grasped is located. A series of small movements would then be necessary to orient the gripper precisely. The arm could then move in and grip the object.

The second movement I tried turned out to be easier than the first. I put a rubber stamp in the gripper and programmed the arm to repeatedly ink the stamp and stamp a piece of paper. Again, this cannot be done in one movement — this time not due to joint slippage, but due to the efficiency of the program. The control program moves the arm from point A to point B in the most direct fashion. You must emulate the human action of down-up, move laterally, down-up, move back, down, etc. The quality of the result was not great, but I was impressed by it. The six-point movement was executed smoothly and accurately over hundreds of sequences. I raised the ink pad and the paper slightly, so that the arm pressed down firmly on both objects.

My third test movement turned out to be quite easy, once I had learned the lessons from the previous two movements. I programmed the arm to pour water from one paper cup into another one. Then it poured the contents of the second cup

back into the first cup. It can do this a hundred times without spilling a drop.

As I mentioned, movement repeatability is quite good. I had the arm hold a fiber-tipped pen, dab on a piece of paper, pick up the pen, rotate the whole arm through 360 degrees, and repeat the movement. Most of the variation in the mark on the paper was due to the pen slipping in the gripper. The series of dots, however, occupied a space no larger than a quarter (2.5 cm. diameter).

Although the brochure from Colne Robotics shows the Armdroid writing its own name, it would take many hours to accomplish such a programming feat.

The Armdroid manual explains how you can write your own movement control program by activating the motors in any desired sequence and for any duration. You can do this by suitable machine-code subroutine calls. The main program, of course, does this at a high level. If you want practice writing your own arm-control programs from scratch, then the software provided is an excellent laboratory from which to start. I must confess that I found this process straightforward, but tedious. This has nothing to do with Armdroid, but rather is a fact of life. I think that it would be good practice for programming other devices that are not equipped with a high level command program. For example, it is possible to write a classical robotic program line such as, *turn wrist 10 degrees*, from the software instructions provided.

SUMMARY

So what good is the Armdroid? It is mainly an educational tool. It helps you explore arm mechanics and movement sequencing. You can learn about interfacing and how to create programs to accomplish complex activities. Since you can immediately see the results of your work, the process is quite rewarding.

The Armdroid I is a well-made piece of hardware that comes with a user-friendly manual and control program. It is an easy-to-learn, inexpensive, educational or experimental robot arm. □

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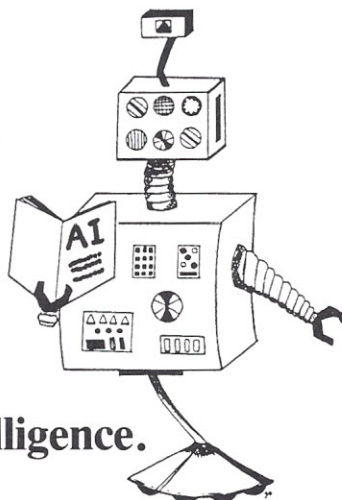
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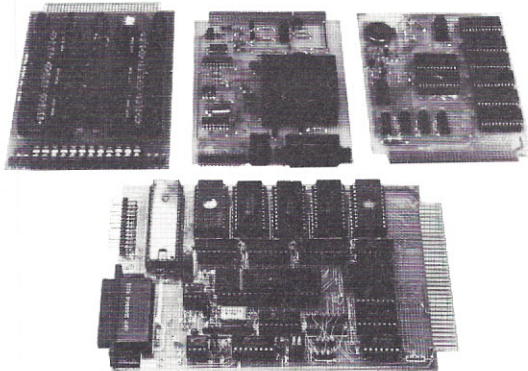
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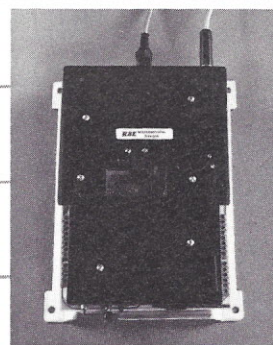
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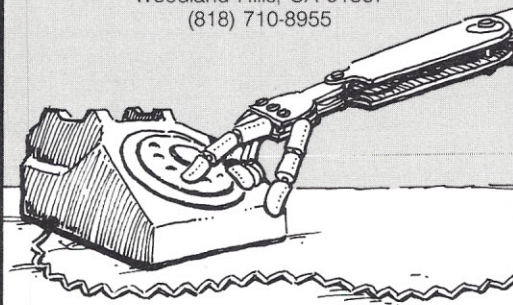
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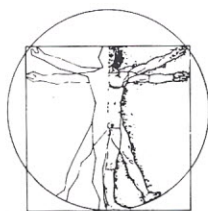
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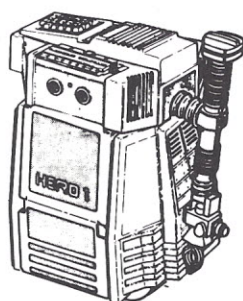
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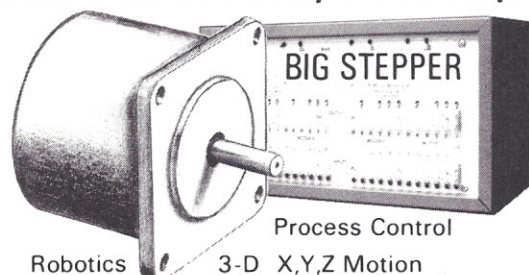


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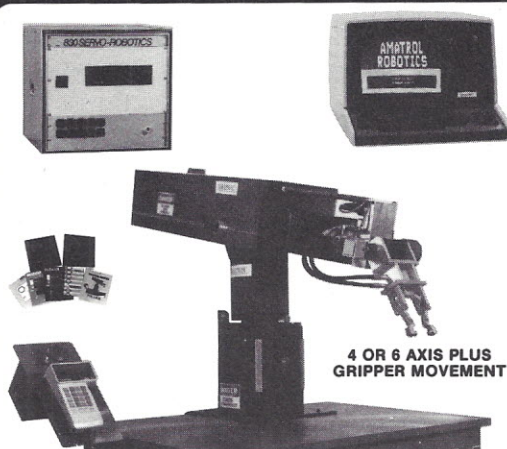
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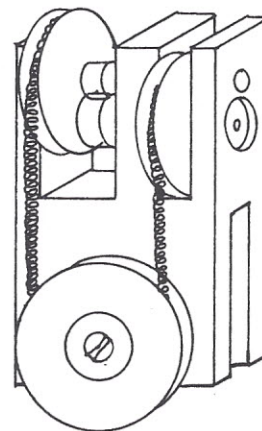
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Editorial

Continued from page 3.

to have this capability, I still can't be convinced that the problems this application poses are anywhere near solved. Designing a robot with a built-in vacuum cleaner is simple. Trying to deal with a cluttered house with constantly rearranged furniture, moving pets, and curious children is the difficult part. But what if we simplified the problem?

Let's define a hypothetical maze. The basic maze structure never changes. It is composed of long, parallel corridors which meet at T-intersections. The floor height never changes, no movements from rugs to wooden floors, etc., and the robot will rarely need to react to a moving object. Now the task has been considerably simplified. This constrained environment is typical of many supermarkets, hardware stores, and discount stores. I'm sure many shop owners would like to have their floors vacuumed and polished each night. Adding smoke, fire, and intruder detectors would further increase the robot's usefulness.

Or, how about a robotic machine that vacuums and polishes auditorium floors? Typically, people remove all the chairs and obstructions from the auditorium before cleaning. They then repeatedly take the vacuum or polisher up and down the length of the auditorium. Basically, what they are cleaning is a large, empty box. A suitably powered robot turtle with accurate ranging capabilities would be very useful in this situation. Various algorithms could be designed to ensure that the robot covers the entire area. Since most of the walls would be fairly regular, the robot could use a general-purpose algorithm for most of the area. Special procedures could be developed on a case-by-case basis for any unusual shapes or situations encountered on a particular job.

There is nothing wrong with telling the robot precisely what to do. The first guideline for constructing service robots should be, "Don't try to build a general-solution, do-everything robot. Build a machine that does a particular job, and does it well." If it is necessary to develop special code for a specific situation, do it. Nice general-purpose solutions may be technologically elegant, but they are not always the best solution to a problem. In the auditorium-cleaning example, any special routines needed to solve a specific problem would need to be developed only once and could be used for years.

Another design consideration for service robots is cost. Service robots should be *economical*. An economical robot design does not necessarily mean it is cheap. An economical design is one that does a job well *and* is comparably priced, or less costly, than the current methods. A robot that cannot perform its destined task as well as

and as cheaply as it is being currently done by people is not worth designing. If you can show a businessperson that your service robot will save money, you have taken the first step towards a sale.

KEEP THEM RUNNING

Service robots should be built to last several years under continuous use and abuse. They should be sealed so that the outside world's dust and dirt cannot get in and lubricants or battery chemicals cannot get out. Nobody wants a messy robot running around the office. How about cleaning the robot itself? Maybe they should be designed to run into a shower to rinse off.

No matter what office or business environment a service robot is used in, it will always be subject to abuse. People will drop things on it, children will kick it, and, no matter how well it is designed, it will run into the occasional wall. Be prepared: build the robot to be overloaded, overused, and undermaintained. The robots should be so well constructed that the term "built like a Mack truck" would someday be replaced by "built like a service robot."

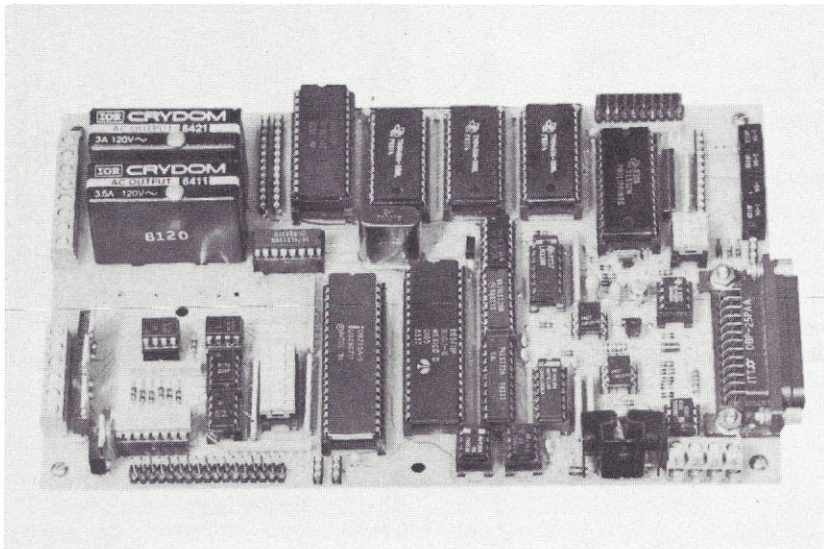
Service robots should also be easy to repair; not simple, mind you—just easy. *Easy to repair* does not mean that anyone can fix it. After all, you might change the oil in your car and check the battery fluid level, but most people bring the car to the service station for repairs. Likewise you should be able to perform the day-to-day maintenance on a service robot without having a degree in mechanical engineering. If something really goes wrong, you could always bring it back to the shop.

IT WORKS, GUARANTEED

I'll close with one last thought. Guarantee your product. When I buy my service robot, I would like to know it will function for some time or the manufacturer will correct the problem. The 30-day guarantee which seems to be standard throughout most of the microcomputer industry is just not sufficient. In 30 days, I expect a service robot to just be getting broken in, not broken down.

Perhaps service robot manufacturers will need to develop a guarantee similar to the automotive industry. Perhaps a guarantee for 1 year or 1000 windows might become an industry standard. □

New Products



Forth Controller

The PROATROL single-board control system functions as both a development system and a powerful dedicated stand-alone controller. It is available as a standard board, programmable by the user with a personal computer or terminal, or, at additional cost, preprogrammed to customer requirements.

Based on the Rockwell R65F single-chip microcomputer, the board contains a Forth operating system in its internal read-only memory. The 5 by 8 in. PROATROL board includes onboard I/O options with RS-232

and 20 mA serial interfaces, plug-in sockets for I/O modules, an analog-to-digital converter, half-bridge power drivers, optically isolated inputs, potentiometers for level or speed settings, DIP switch inputs, open collector outputs, +5 V regulator, in-circuit EEPROM programming, sockets for up to 14 Kbytes of memory, and bus expansion.

For further information, contact: Conrad Seagroves, VP Marketing and Sales, PROA Corp., 4019 Edith NE, Albuquerque, NM 87107, telephone (505) 344-2106.

Circle 20

Real-Time IBM PC Operating System

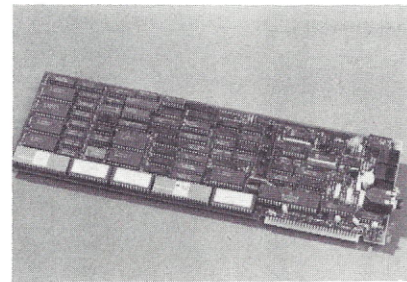
MTOS-86, the real-time multitasking operating system developed by Industrial Programming, Inc. for the 8086/8088 is now available for the IBM PC and compatible machines. Designated MTOS-86/PC, the system allows the PC to be used in a wide variety of control and data acquisition applications, including factory automation, chemical process control, and alarm reporting systems.

MTOS-86/PC has full control of the PC and all its peripherals, including keyboard, disk drives, timer, interrupt controller, and process I/O systems. The system allows users to attach custom hardware drivers.

MTOS-86/PC is distributed on diskette in PC format. The disk includes the executive, console driver, debugger, a run-time interface for the Intel C compiler, and a test/demonstration program. Price for a single copy of MTOS-86/PC is \$495. User-level manuals are included. Technical support is available for an annual fee of \$125. The support fee includes one complete set of updated diskettes per year.

MTOS-86/PC is available from Industrial Programming, Inc., 100 Jericho Quadrangle, Jericho, NY 11753, telephone (516) 938-6600.

Circle 21



Voice Card Replaces Keyboard

Voice I/O functions are now available for the IBM and IBM bus-compatible computers. The VPC 2000 Voice Card from Votan provides voice recognition, speech generation, and telephone management capabilities on a single plug-in card. With the accompanying software utility, Voice Key Software, you can use the Voice Card immediately for speech command and control of programs you currently use on your PC. The Voice Card allows you to define up to 64 utterances that are linked to sequences of keystrokes up to 30 characters in length. At runtime, the card listens for voice commands and automatically types the key strokes linked to each command when it is uttered.

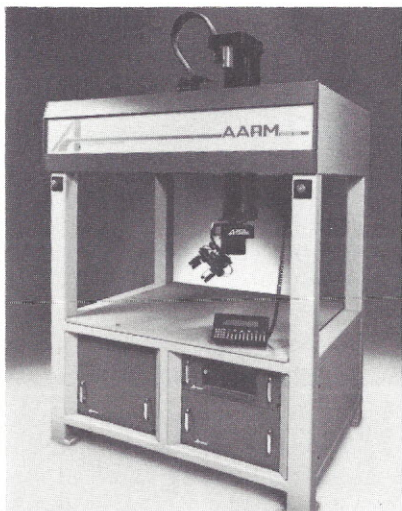
The Voice Card features Votan's newest technology, continuous speaker-dependent recognition (CSDR), which allows an individual to speak to the computer in a normal conversational flow, without pauses between words. A *word spotting* capability will pick out target words located anywhere within a stream of normal conversation.

According to Votan, their technology is the only commercially available speech recognition system that operates over standard telephone lines. This ability allows you to talk to your PC from remote locations, as well as have it respond verbally. Telephone capabilities provided by the Voice Card include auto answer, autodial, DTMF encoding and decoding, and others. The Telephone Manager software program provides immediate access to these hardware facilities.

The single Voice Card board, microphone, speaker, software, and documentation are listed at \$2,450. For more information, contact: Votan, 4487 Technology Drive, Fremont, CA 94538, telephone (415) 490-7600.

Circle 22

New Products



Adaptive Touch Robot

Adaptive Intelligence Corp has announced an all-electric robot designed specifically for high-speed precision, small parts assembly. The robot, called AARM for Adaptive Assembly Robotic Machine, is an overhead gantry type which uses what the company terms an intelligent gripper *adaptive touch* feature to feel for part locations. Digital servo design combined with optical encoders is employed for accurate positioning with ± 0.001 in. repeatability.

The AARM system provides three programming methods: teach pendant, on-line or off-line program development with an IBM PC. Adaptive Intelligence has developed a high-level interactive and extensible programming language to make both on-line and off-line programming easy, fast, and versatile.

For more information, contact: Jim Breen, VP Sales, Adaptive Intelligence Corp., 2944 Scott Blvd., Santa Clara, CA 95050, telephone (408) 970-0777. Circle 23

Color Control

For less than \$150, TRS-80 Color Computer users can add a B-80 module and control as many as eight AC loads. The B-80 module plugs directly into the computer's Program Pak socket and uses BASIC language instructions for programming all input/output functions. The B-80 accepts as many as eight inputs, either from the controlled loads or from other points such as panel switches, limit switches, etc.

The module accepts six switching or logic level inputs (5 VDC) and two voltage comparator inputs (to ± 12 VDC). The B-80 provides eight outputs rated for 115 VAC @ 0.5 A with 2500 VAC isolation between loads. Operating temperature is 0 thru 70°C. No special power supply is needed; the unit



operates from the TRS-80 Color Computer supply. Board size is 4 by 6 in.

Unit price is \$137.25 in small quantities. For more information, contact: James R. Dyne, Sales Manager, New England Instrument Co., Kendall Lane, Natick, MA 01760, telephone (617) 875-9711. Circle 24

Mechanical Design Notes

Mechanical engineers will find many useful suggestions in a series of technical bulletins issued by CAM Technology, Inc. The latest, "Useful Relationships Between Cam Curvature and Acceleration Force," provides a simplification of the standard radius of curvature formulas which apply rigorously in special but frequently encountered cases and offers approximations to many more. The bulletin permits such determinations as acceleration forces directly from a radius trace of a physical cam segment and quick assessment of the undercutting limitations of a contemplated cam design.

For a copy of Technical Bulletin #12, write or call Ted Weber, Jr., Chief Engineer, Cam Technology, Inc., 369 Bradhurst Ave., Hawthorne, NY 10523, telephone (914) 747-0006. Circle 25

New Robot Publication

Personal Robotics Magazine, is devoted exclusively to people interested in the field of personal robotics. The premier issue included an article comparing three of the most popular robots, HERO 1, the RB5X, and Androbot's BOB. The issue also contains news of the personal robot industry and essays with thought-provoking ideas. The goal of *Personal Robotics Magazine* is to provide both present and potential owners of personal robots with useful information, and to provide a forum for personal robot users. A subscription to the bimonthly magazine is \$12.00.

For more information, contact: PRM-Subscription Department, PO Box 421, Rheem Valley, CA 94570. Circle 26

Z8 Operating System

Micro-EZ/OS is a real-time, multitasking operating system for the Z8 family of single-chip microcomputers. Micro-EZ/OS is designed to be a base for application program development. The system supports the system designer in developing real-time control applications. Micro-EZ/OS is compact and uses only 400 bytes of program memory and 10 bytes of data memory. Designed to

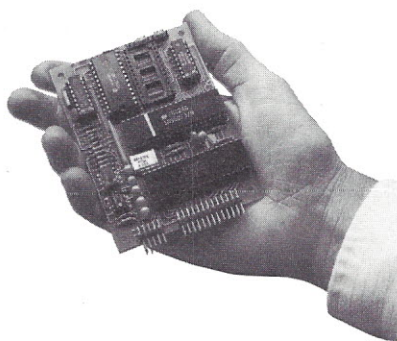
lower new product development costs and improve system reliability, Micro-EZ/OS allows up to 16 concurrent control tasks to execute in a single-chip or expanded-hardware environment. Standard functions, such as display driving and keyboard scanning, can be implemented as separate control tasks. Built-in system services provide memory allocation, time base assignment,

task synchronization, and scheduling functions.

Available on ISIS or CP/M diskette, or EPROM, the \$750 package includes a complete user's guide and examples of ready-to-run application tasks. For more information, contact: Ed Thompson, Micro Computer Control, PO Box 275, Hopewell, NJ 08525, telephone (609) 466-1751. Circle 27

New Products

Low-Cost Controller with BASIC

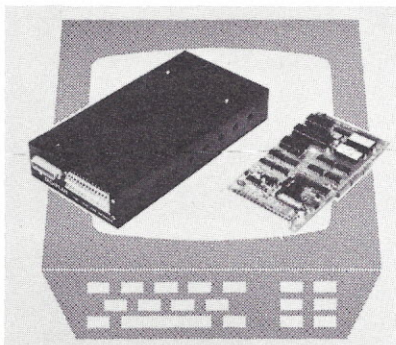


The MC-IN is a versatile, self-contained, single-board microcontroller system that is quick and easy to program with its resident Tiny BASIC interpreter. By simply applying 5 V and connecting an RS-232 compatible terminal, program development may begin. The resident Tiny BASIC language allows you to type in and immediately execute your programs in a high-level language.

The 3 by 4 in. board contains a 4.0 MHz INS8073 processor with resident Tiny BASIC Interpreter, real-time clock, 2 Kbytes of programmable memory, a socket for 2716 or 2732 EPROM, RS-232 connector, and 29 I/O lines including two interrupt inputs and three flag outputs.

The MCIN microcontroller is priced at \$139 in quantities of one. For more information, contact: Basicon, Inc., 7713 SW Nimbus, Bldg. 31, Beaverton, OR 97005, telephone (503) 626-1012. Circle 28

IEEE-488-Compatible Stepper Motor Drive Interface

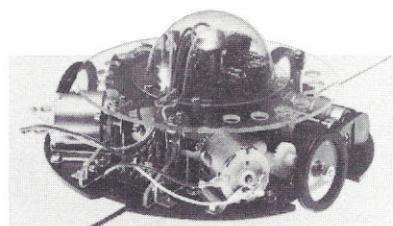


The 1185A from PKS-Digiplan, Ltd. enables one or more stepper motor drives to be controlled directly by any processor or programmable calculator having an IEEE-488 bus facility. The 1185A eliminates the need for specialized hardware and allows the use of a high-level language such as BASIC, FORTRAN, or C for motor control.

The 1185A is based on an Intel 8039 microprocessor. Connection to the IEEE-488 Bus allows designers to economically daisy-chain a multi-axis system. If it is necessary to move numerous motors at the same time, the 1185A can drive up to 42 separate axes simultaneously.

For more information, contact: Impact, 550 St. Charles Dr., Suite 107, Thousand Oaks, CA 91360, ATTN: PKS.

Circle 29



Movit Line Tracer

Stock Model Parts is marketing the Movit line tracer robot which utilizes an infrared light sensor to follow any black line. A black felt tip marker or tape can be used to create a straight or curved pathway, at least 3/8 in. wide, on any white paper or white floor area. Applications include school science projects and robotics courses.

The three-wheeled robot is offered in easy-to-assemble kit form. All electronic circuits are contained in two pre-assembled and pre-tested printed circuit boards. Only mechanical assembly is required. The 5 1/2 in. diameter, 2 1/2 in. high robot consists of 55 major components plus over 130 fasteners. The robot's power source consists of one 9 V battery and two AA batteries (not included).

For more information about the \$44.95 Line Tracer II robot, contact Stock Model Parts, Division of Designatronics, Inc., 54 South Denton Ave., New Hyde Park, NY 11040, telephone (516) 328-3333.

Circle 31

PIC Your Gears

PIC (Precision Industrial Components) Design publishes two catalogs of standard precision mechanical components including gears, shafts, bearings, mounting assemblies, couplings, clutches, belts, lamps, speed reducers, gear boxes, dials, knobs, hangers, and springs.

PIC caters to both the OEM purchaser and the purchaser requiring prototype quantities. The catalogs also contain a chapter describing a series of educational and prototype kits. Of particular interest is the "Electromechanical Control Systems Educa-

tional Kit" which demonstrates transducer input and output, feedback, proportional control, motor speed characteristics, response time, systems lead/lag time, gear ratios, loading, and analog control.

Catalog 38 contains a full complement of components specified to English measurements. Catalog M1a is its Metric counterpart.

To receive copies of the catalog(s), contact: PIC design, PO Box 1004, Benson Rd., Middlebury, CT 06762, telephone (800) 243-6125, or (203) 758-8272.

Circle 30

Nitinol for Sale

TiNi Sales is a supplier of nitinol, a shape memory effect alloy made from nickel and titanium. Their nitinol product is a drawn wire which can be used for various experiments. A 1 ft. length of wire costs \$6.00, a 10 ft. length costs \$40. TiNi Sales also sells a manual titled *How to Work With Nitinol* which should be very instructive to anyone wanting to work with various shape memory alloys. The manual describes how to shape, anneal, and train nitinol and contains several project ideas.

The TINI-1 Engine is a heat-activated engine which uses SMA motion as its motive force. The engine requires only cupfuls of hot and cold water to start operating.

For more information about nitinol products and the TINI-1 Engine, contact TiNi Sales, 3593 Boyer Circle, Lafayette, CA 94549.

Circle 32

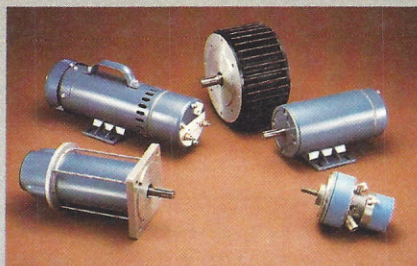
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